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THE ORIGIN OF SPECIES IN NATURE[1]

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AMONG the duties of the botanist is that of adding to the number of known species, varieties and forms. To reach this end several ways are open. One may, by studying the flora of new or insufficiently explored areas, not only extend the range of species formerly known, but add new species. The work of Setchell and his students, especially Gardner, done on the algal flora of the Pacific Coast, yields an excellent illustration.[2]

Sometimes it is possible to correlate with such investigations work of economic value. The results obtained by agricultural explorers working under the auspices of the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry, U. S. Dept. of Agriculture and other[3] institutions, offer a case in point. Such work, to lead to the desired result, requires men of especial fitness, physical, moral and mental. Not only must they possess physical endurance to overcome the hardships with which they necessarily meet. Moral courage, moral strength are necessary to extricate them from the many

[1] Read, through the courtesy of Mr. Henry W. Anderson, before the Academy of Science of St. Louis, May 15, 1911. Contributions from the Botanical Laboratory of the University of Michigan, No. 125.

[2] Univ. Calif. Publ. Bot., 1[3] et seq., 1903–1910.

[3] Hansen, N. E., "The Wild Alfalfas and Clovers of Siberia, with a Perspective View of the Alfalfas of the World," Bull. No. 150, B. P. I., U. S. D. A., 1909.

Aaronsohn, A., "Agricultural and Botanical Explorations in Palestine," Bull. No. 180, B. P. I., U. S. D. A., 1910.

difficult positions in which they are bound to find themselves and to bring to a successful end the undertaking upon which they have embarked. Further, a thorough knowledge and an excellent judgment are essential. Yet none of these are sufficient unless they be complemented by an all-pervading love for the subject, a devotion which counts all obstacles as naught and persists in the face of difficulties which to most men would appear unsurmountable. Frank Meyer, agricultural explorer, now, for the second time, exploring eastern Asia—last heard of when entering Thibet—exemplifies this ideal. Such are the men who on their return to the civilized world bring back with them the rare plants which delight the collector and which, in themselves frequently of apparent insignificance, in a few years add immensely to our collections. The discovery of *Nicotiana Forgetiana*[4] is, in recent years, perhaps the most widely known instance through the part played by this species in the introduction to our gardens of *Nicotiana Sanderæ* (*N. alata* × *Forgetiana*). But not always is it necessary to draw on the flora of distant countries. By thoroughly going over a well-covered territory one may be able to add new varieties of a more or less well-known species, such as was the case with *Oxalis stricta viridiflora,*[5] which, since the time of publication of the original paper, has been found near Thomson, Ga.[6] This plant, since the spring of 1909, has established itself in the Ann Arbor experiment garden, spreading rapidly from seed selfsown in the latter part of the same summer. The plants grow in the open as well as in more shaded places and on a light, sandy soil. The varietal character maintains itself perfectly, as it does in the Missouri Botanical Garden, where, on a recent visit, I saw a bed of it, in the open and on a fairly heavy soil. Though there is a certain amount of variation in the intensity of the green coloring of the

[4] *Curtis' Botanical Magazine,* 4th Ser., **1**, pl. 8006, 1905.

[5] Hus, H., "Virescence of *Oxalis stricta*," Ann. Rep. Missouri Bot. Gard., **18**: 99, pl. 10, 11, 1907.

[6] Bartlett, H. H., "On *Oxalis stricta viridiflora*," *Rhodora,* **11**: 118, June, 1909.

flower, due to a variation in the relative amounts of chloroplasts and yellow chromoplasts, the plant appears to have undergone a sufficient number of fairly rigid tests, under widely divergent conditions, and for a sufficient number of generations (9), to entitle it to recognition as a distinct, non-pathological variety. The variation in the color of the flower I am inclined to ascribe to differences in light intensity. In a bed, situated in the middle of the experiment garden, *i. e.*, in an open place where no obstruction prevents full and direct illumination, the flowers are uniformly green. When the plants are grown in the greenhouse or in the shade of shrubs, there seems to be a tendency for the flowers to assume a more yellow tinge. But not in a single instance has a flower been observed which possibly could have been mistaken for one of the species.

Again it may be that a form deserving specific rank is discovered, as instanced by the now well-known *Capsella Heegeri*.[7] Such discoveries possess an added charm since in these cases the possibility of a recent origin of the new form is not excluded. Sometimes it is possible to prove this experimentally, as was done by de Vries for his evening primroses. An illustration of probably recent origin and of repetition of mutation is yielded by the discovery of a single specimen of the *inermis* variety of *Cynara Cardunculus* in Algiers by Trabut.[8] But some years ago what would seem to have been the same variety was grown in the St. Louis experiment garden from seed which my father kindly obtained for me from the then director of the Botanical Garden at Buenos Aires and the ancestry of which I understand was to be traced to an individual growing wild in the vicinity.[9]

[7] Solms-Laubach, H. zu, "Cruciferenstudien—I, *Capsella heegeri*, eine neuentstandene Form der deutschen Flora," *Bot. Zeit.*, **55**: 167, pl. 7, 1900.

[8] Trabut, L., "Sur une mutation inerme du *Cynara Cardunculus*," *Bull. Soc. Bot. Fr.*, **57**: 350, 1910.

[9] *Cynara Cardunculus*, a native of the Mediterranean region, emigrated to South America, where it occupies large areas (Darwin, "Animals and Plants under Domestication"). An analogous case is that of *Silybum Marianum*, likewise a native of the Mediterranean region and now largely

Generally speaking, the investigation of the flora of a newly discovered or formerly inaccessible region is a matter of choice or, better, perhaps, opportunity. The same is true for the detailed study of our collective species, leading to a recognition of component elements as illustrated by the work of Small on *Oxalis,*[10] *Rhus,* etc. Whoever can devote a part of his time to the study of a genus is able to establish the existence of differences which, formerly ignored and in themselves slight, are of the greatest importance for the tracing of relationships. Unfortunately, perhaps, in such studies there is usually developed a mass of detail so great, so intricate that none but a few specialists are able to recognize the various forms. *Hieracium, Aster, Cyperus* are names sufficient to strike terror in the hearts of any but the most ardent systematists. But before such a detailed study can be made there must be gathered, in the first place, herbarium material. It is not sufficient to possess a single specimen. Material must be collected from various habitats and both during the flowering and fruiting periods. Often there are differences between the leaves of old and young shoots, as in *Cratægus.* Or the leaves of the fruiting branches may be different from those of purely vegetative shoots as in *Hedera Helix. Ficus* and *Pothos* both may show leaves of a very different character.[11] None would at first sight believe leaves of seedlings or of adventitious shoots of *Eucalyptus globulus* and those of older specimens to belong to the same species. Many species of *Acacia* show, during the first few years of their existence, well-developed phyllodes which later disappear entirely. Sometimes even the leaves on the same

naturalized in California where it forms a common and, on account of its leaves, a most conspicuous weed.

[10] "North American Flora," **25**[1]: 25, 1907.

[11] In the greenhouses of the Missouri Botanical Garden may be seen a very fine specimen of *Ficus repens* which near the ground and up to a height of some eight feet, produces the small leaves typical of this species. When, however, the plant makes a bend to twine horizontally along a rod, large leaves are produced. Other instances are given in de Vries's "Species and Varieties," Ch. 15.

shoot may present a very different appearance. And while this is something not entirely unexpected in hybrids as in *Quercus Leana* (*Q. coccinea*×*imbricaria*) and Boston fern hybrids, it is a source of astonishment when this occurs in species which we do not believe to be of hybrid origin. Heterophylly is a matter of common observation in the ubiquitous horseradish, *Radicula Armoracia. Sterculia diversifolia,* commonly cultivated in greenhouses, has leaves which are mostly ovate to lanceolate in outline and which are often entire or variously three- to five-lobed on the same shoot. The sassafras, *S. variifolium,* illustrates the same principle, in fact, derives its name from this feature. The paper mulberry, *Broussonetia papyrifera,* shares the irregular lobing of the leaf with its near relatives, *Morus rubra* and *M. alba.*[12] The cut-leaved Persian lilac is very variable in this respect.[13] Sometimes seasonal differences are so great as to make collecting throughout the year an absolute necessity,[14] an instance so strikingly illustrated by *Viola palmata.* In woody plants there is not infrequently a return to the nepionic stage in the leaves produced near the base.[15] When we remember that heterochromatism[16] may add a further complication, it becomes evident that it is not sufficient to be able to refer to herbarium specimens only. The living plant must be studied in its various stages of development. It is by this means only that one may arrive at a true estimate of the stability and significance of minute details.

[12] Rep. Bot. Dep. New Jersey Agric. Coll. Exp. St., 325, pl. 21, 1909. Fry, A., "Note on Variation in Leaves of Mulberry Trees," *Biometrica,* **1**: 258, 1902.

[13] Masters, M. T., "Vegetable Teratology," fig. 177. See also, Schlechtendal, *Bot. Zeit.,* **13**: 559, 1855, and Lloyd, *Torreya,* **2**: 137, 1902.

[14] Cushman, J. A., "Studies of Localized Stages of Growth in some Common New England Plants," AM. NAT., **36**: 865; *ibid.,* **37**: 243, **38**: 819.

[15] Jackson, R. T., "Localized Stages in Development in Plants and Animals," *Mem. Boston Soc. Nat. Hist.,* **5**[4]: 89, 1899.

[16] Kerner von Marilaun, A., "The Natural History of Plants," **1**: 149; **2**: 569.

Trelease,[17] in a recent paper on his favorite agaves, says: "... my own conception of specific identities and differences in the genus oscillates as my study proceeds...."

While ultimately work of this nature, conscientiously carried out, leads to a clear delineation of the characters peculiar to each species, subspecies, variety, etc., there is reached, usually not so very long after the inception of the work and very long before its termination, a period of chaos which, to say the least, is the reverse of stimulating and ordinarily sufficient to dampen the ardor of the greatest enthusiast. Thus, in my cultures of local forms of *Capsella Bursa-pastoris*, the four forms described by Shull[18] and some of those of Almquist[19] can be recognized readily. But there remain so many whose classification is doubtful at the present time that it would cause Mr. Murdock, associated with me in this investigation, and myself to throw up our hands in despair, were it not for the fact that there have appeared in our cultures extreme forms, so striking and so different from any previously described, that we are inclined to believe we are possibly dealing with mutations in the sense of de Vries (Fig. 1). Research along these lines requires long and tedious experimental efforts. It is a different matter where the finding of distinctly new forms in an old territory is concerned. Here an element of chance largely enters. By increasing the number of our observations our chances of discovering something new may be increased materially. In other words, directly or vicariously a large amount of ground has to be covered. Yet I am not satisfied that a thorough knowledge of a comparatively small area would not lead to equally satisfactory results. The one requires about as much exertion as does the other and certainly the

[17] Trelease, W., "Species in *Agave*," *Proc. Amer. Phil. Soc.*, **49**: 232, pl. 32, 33, 1910.

[18] Shull, G. H., "*Bursa Bursa-pastoris* and *Bursa Heegeri* Biotypes and Hybrids," Carn. Inst. Publ., No. 112, 1909.

[19] Almquist, E., "Studien ueber die *Capsella Bursa-pastoris* (L.)," *Acta Horti Berg.*, **4**, No. 6, 1907.

number of observations is identical. But the greater familiarity with the territory and the fact that observation may be continued throughout the seasons offers certain advantages. It is a question which must be decided for individual cases by every investigator along this line,

FIG. 1. Appearance of a new form among seedlings of *Capsella Bursa-pastoris*. ×1.

since its answer must depend on local conditions, such as proximity to residence, climate, whether arid or temperate, etc. A garden, for instance, offers as good if not better opportunities to observe the appearance of new forms as does the field. Here all the requirements for such work are met with, *i. e.*, large numbers grown under highly favorable conditions. Parks, nurseries and especially the larger botanical gardens, where are kept accu-

rate records of the histories of the various plants grown, constitute an important field. Thus, in the Missouri Botanical Garden, there are grown every year numerous plants of *Bellis perennis* "delicata." In 1906 the seed for these specimens was obtained from a Philadelphia seed firm. The seed was sown and the plants were handled in the usual manner until they finally found their way to the beds used for decorative purposes. It was while the plants, several thousands in number, were in this position, that the attention of Mr. Shelby Jones, at that time a student at the garden, was attracted to a plant because of the abnormal character of its flowers. In the capitula of this specimen the rayflowers had either disappeared, or, what is more probable, had been replaced by

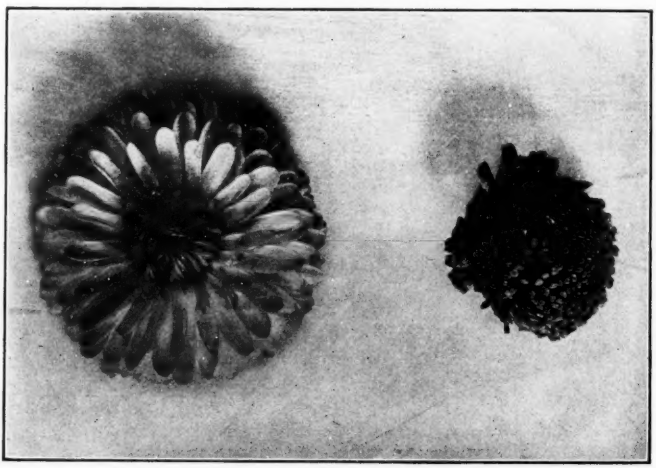


FIG. 2. Capitula of *Bellis perennis* "Delicata" and *Bellis perennis discoidea*. ×2.

disc-flowers. The result was a rather striking, maroon-red button, in sharp contrast with the normal heads (Fig. 2). For in the normal form of the variety under cultivation the upper surface of the ligules was either white or rose-colored, while the lower surface was red. In the discoid variety, owing to the tubular nature of the transformed

rayflowers, the white coloring disappeared from view. It is an instance of change of color analogous to that of the cactus dahlia, though differing in one striking feature. For in the latter case the brilliancy of the flowers is due to the recurved rayflorets which show the bright color of the upper surface instead of the dull shade of the lower one, exposed to view in the older form of dahlia.

The plant was segregated and propagated vegetatively, as many as one hundred specimens being on hand at a time. Among these not a single instance of a return to the conventional form was observed. Of course, it would have been far more interesting to note the result of sexual propagation, a proceeding which was rendered impossible by the failure of the flowers to produce good seed. This, however, is quite in accordance with the experience of horticulturists, *fide* André.[20] In this most comprehensive publication the variety *discoidea* is mentioned under the name of "Paquerette vivace var. double a fleurs tuyautées," its slight fertility noted and attention called to the fact that the seed for such plants must be collected from flowers which are almost double. It is added: "leur tendance a doubler est assez bien fixée pour qu'on ne trouve dans le semis presque plus de fleurs de duplicature imparfaite." In this connection Master's notes published in the appendix to his "Vegetable Teratology," and de Vries's remarks on *Matthiola incana fl. pl.*[21] are of considerable interest. Penzig evidently refers to a similar form,[22] though his use of the term "ox-eye daisy" for this form appears to be contrary to usage, it being reserved ordinarily for *Chrysanthemum Leucanthemum*. Similar instances are not rare among Compositæ and are illustrated by *Matricaria* (*Chamomilla*) *discoidea* and *Anthemis tinctoria discoidea*. Very frequently one is able to find a few tubular flowers among the rayflowers of our cultivated com-

[20] Vilmorin-Andrieux et Cie, "Les fleurs de pleine terre," 5th ed., R.-Ed. André, éditeur, 781, Paris, 1909.

[21] De Vries, H., "Plantbreeding," 238, Chicago, 1907.

[22] Penzig, O., "Pflanzen-teratologie," **2**: 59, Genoa, 1894.

posites, especially *Cosmos* and *Coreopsis*. Some of my earliest experiments, undertaken to study the effect of selection on such deviations, yielded negative results. De Vries[23] describes and illustrates a *fistulosa* variety of *Dahlia variabilis* which appeared among his cultures. Among chrysanthemums such "quilled" forms are not rare. "Enterprise" is a variety which illustrates this type and which not infrequently is met with at chrysanthemum exhibitions.

Next to gardens, cultivated fields, *i. e.*, places where a large number of individuals of the same species or variety are grown, offer the best opportunity for the discovery of new or aberrant forms. One only has to be reminded of the case of the beardless Anderbeck oats.[24] In a similar manner there was found, among the numerous alfalfa plants which occupy a large portion of the acreage of the garden, a white-flowered specimen, the flowers of which, on fading, became almost yellow. Since then there were found in a neighboring field, a group of such white-flowered plants.

Color varieties are among the deviations most frequently noted, perhaps because the resulting change is particularly easy of observation. They occur both as to flowers, as for instance in *Lobelia syphilitica alba, Trifolium pratense album,* etc., and as to fruits, as instanced by *Gaylussacia resinosa leucocarpa*,[25] *Vaccinium pennsylvanicum leucocarpum, V. corymbosum atrococcum* f. *leucococcum, V. canadense chiococcum*.[26] White strawberries of course are well known. Yellow-fruited varieties exist of *Ilex myrtifolia*[27] as well as of *Ilex opaca* and *I. verticillata*. The Californian holly, *Heteromeles arbutifolia,* also has a yellow-berried variety.[28] *Calli-*

[23] De Vries, H., "Mutationstheorie," **1**: 480, fig. 134.

[24] De Vries, H., *loc. cit.*, 59.

[25] Porter, Thos. C., "Additions to our Native Flora," *Bull. Torr. Bot. Cl.*, **16**: 21, 1889.

[26] Deane, W., "Albino Fruits of Vacciniums in New England," *Rhodora*, **3**: 263, 1901.

[27] Harper, R., "*Ilex myrtifolia* with Yellow Fruit," *Torreya*, **2**: 43, 1902.

[28] *The American Botanist*, **15**: 49, 1909.

carpa americana and *Rubus cuneifolius* both possess white-fruited varieties.[29]

Of *Solanum nigrum* there exist, besides the black-fruited form, one with yellow and one with green fruit. *Atropa Belladonna* exhibits the same color forms of the fruit which to us are familiar in the cultivated peppers, viz., red and yellow. Finally, in shrubs which are grown chiefly because of the coloring of the bark, for instance *Cornus stolonifera,* with a red bark, there may be met with forms which have a yellow bark. So numerous are references to color varieties in our literature and these variations are met with so often that their frequency suggests facility of origin perhaps parallelled only by that through which dwarf forms are produced. For several years, on collecting trips in the vicinity of St. Louis, Mo., all patches of *Lobelia cardinalis* were examined with particular care for white-flowered plants, since they were known to exist in various parts of the United States. Though these observations did not lead to the desired result, Mr. O. S. Ledman, of St. Louis, was able to find on the peninsula in the northern portion of Pittsburg Lake, St. Clair Co., Ill., opposite St. Louis and in a locality with which I believed myself to be thoroughly familiar and had searched most carefully on several occasions, some plants of *Lobelia cardinalis alba.*

This would indicate that the formation of the white-flowered variety had taken place recently, though the possibility of transportation from other localities, though improbable, is not excluded. That a white-flowered form of *Medicago sativa* is formed as readily seems likely. Various species belonging to the Leguminosæ possess *alba* varieties. De Candolle speaks of a color variety,[30] and at first it was thought the specimens under consideration could be classed here. Since then, however, there were found in the same alfalfa field several

[29] Rolfs, P. H., "Variation from the Normal," *Asa Gray Bull.,* **8**: 75, 1900.

[30] *Medicago sativa versicolor* (Sér. mss.): floribus luteis coeruleisque. *M. falcata versicolor* Wallr. sched. cort., p. 398. *M. lutea-cærulea* hort., *Prod.,* **2**: 173, 1825.

plants which answer the description of the variety mentioned in the *Prodromus,* more or less. It is more than probable that these plants, the flowers of which exhibit a great variation in color, are to be included under the "variegated alfalfas," for which Westgate[31] suggests the designation "*Medicago falcata* × (*M. sativa*), to indicate that "the hybrids have been recrossed several times with ordinary alfalfa and also among themselves." Hybridization, however, does not explain the white color of the flowers. That white-flowered plants and those with flowers of a yellow or cream color are not of rare occurrence is shown by the data furnished by Westgate[32] who notes such plants among four, respectively five of the forms experimented with. On the other hand, in view of the known existence of white-flowered forms the assumption of the formation of the white-flowered plants at Ann Arbor, through recent mutation, does not seem warranted. At the same time, such a possibility is not excluded, for while we do not believe that hybridization can have as its direct result the production of a new character, or the loss of one,[33] it is not at all improbable that hybridization indirectly may cause a plant to initiate a mutation period. It is expected that the seed gathered from the white-flowered plants will, in the course of a generation or two, yield a pure white offspring. This seems to be the experience of others. Mr. C. V. Piper, of the Bureau of Plant Industry, U. S. D. A., in a reply to a recent letter concerning *alba* varieties of *Medicago sativa* says: "Some of

[31] Westgate, J. M., "Variegated Alfalfa," U. S. D. A., B. P. I., Bull. No. 169, February, 1910.

[32] *Loc. cit.,* 37, Table I.

[33] Instances which may suggest themselves but which obviously fall outside our definition, are in the first place those in which atavism comes into play, such as is the case in a cross between *Datura lævis* and *D. ferox.* (Naudin, *Ann. Sc. nat.,* 5 Sér., **3**: 155, 1865. Reciprocal crosses of the two white-flowered plants yielded a uniform offspring with pale purple flowers. (See also de Vries, "Mutationstheorie," **2**: 44, 201.) More recently, through the work of Cuénot, Durham and Nilsson, another, more plausible, explanation of the reappearance of the purple color can be given. (See L. Plate, "Vererbungslehre und Deszendenztheorie," 1910.)

our selections of these white-flowered forms now breed true."

In connection with this *alba* form I wish to call attention to the local distribution of a white-flowered form of *Solanum Dulcamara,* lately taken into cultivation in the experiment garden. This variety occurs but rarely

FIG. 3. *Arctium minus laciniatum* at Albion, Mich.

in the vicinity of Ann Arbor, chiefly on river and lake shores and in swampy places. But at Albion, Mich., it was found in great abundance, growing in moist situations alongside of the species. While it will take some years to determine the constancy of this variety, there is in my mind no question as to the outcome of the experiment. It is a variety not always recognized in our floras, though evidently met with from time to time.[34] But if we give specific rank to mere color varieties, as we do in the case of *Datura Tatula* and *Datura Stramonium,* why not give taxonomic recognition to the equivalent color variety of *Solanum Dulcamara,* the more so

[34] Collins, F. S., "A Variety of *Solanum* New to America," *Rhodora,* **12**: 40, 1910.

since the addition of such an exceedingly variable character as is pubescence, seems sufficient to bring this about (*Solanum Dulcamara* var. *villosissimum* Desv.)?

The last illustration points to the largest source of new or at least imperfectly known species and varieties, *i. e.*, the native flora. The same rule applies here as in cultivated fields: striking morphological differences most readily attract attention. When the plant normally is possessed of large leaves, as is, for instance, *Arctium minus*, any differences in the foliage become especially noticeable. It is through this fortunate circumstance that we owe to Professor Charles E. Barr, of Albion College, Michigan, the discovery of at least a new locality for the apparently rare laciniate form of the species just mentioned (Fig. 3).

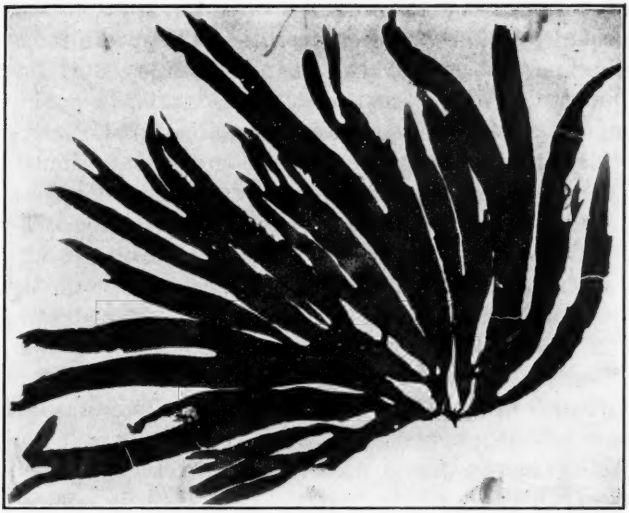
Laciniate forms are of relatively frequent occurrence. We find them not only among the phanerogams and the vascular cryptogams, but even among the algæ one can meet with forms which may be interpreted as such, for instance *Callophyllis furcata* Farlow[35] and *C. furcata* f. *dissecta* Farlow[36] (Fig. 4), though of course there is no connection. One of the earliest accounts of the sudden appearance of a laciniate variety is given by Marchant.[37] In 1715, in his garden, he discovered a plant which, though evidently belonging to the genus *Mercurialis*, was entirely new to him and which did not appear to have been described previously. He named it *Mercurialis foliis capillaceis*. No seed being collected, the next year the same garden spot was anxiously watched. Six plants made their appearance, four of which possessed the character of the plants which had appeared in 1715. The other two were sufficiently different to be segre-

[35] Exsic. in Collins, Holden and Setchell, Phycotheca Bor. Am. Fasc. 18, No. 883, 1901.

[36] Setchell, W. A., and Gardner, N. L., "Algæ of Northwestern America," 306, Univ. Calif. Publ., **1**, 1903.

[37] Marchant, J., "Sur la production de nouvelles espèces de plantes," *Hist. de l'Acad. d. Sc.*, 1719, 57, Paris, 1721.

Marchant, J., "Observations sur la nature des plantes," *Mém. de l'Acad. Roy. d. Sc.*, 1719, 59, pl. 6, 7, Paris, 1721. See also THE AMERICAN NATURALIST, **45**: 493, August, 1911.



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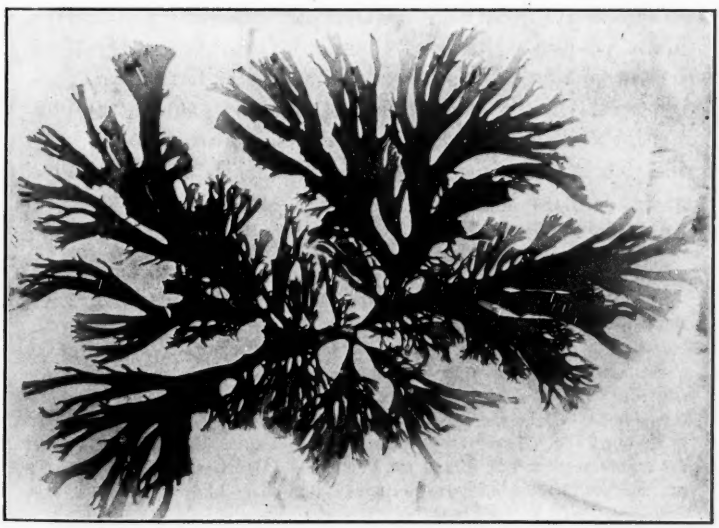

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FIG. 4. *Callophyllis furcata* and *C. furcata dissecta.*

gated under the term *Mercurialis foliis in varias et inæquales lacinias quasi dilaceratis.* They were remarkable chiefly because of their laciniate leaves. Both forms appeared to differ from *Mercurialis annua* in having a longer lease of life, since they remained green until the latter part of December. Plants of both continued to appear in 1717 and 1718, propagating themselves.

Masters and others have given lists containing several instances of the appearance of laciniate forms, to whose number one readily may add by glancing over the catalogues annually published by the principal seed houses. It is especially of trees and shrubs (*Acer platanoides laciniatum, Betula pendula* var. *dalecarlia,*[38] *Rubus fruticosus laciniatus*) that cut-leaved varieties are in demand. This popularity is equaled only by that which *Chelidonium majus laciniatum* appears to enjoy in the world scientific, dating from the time when Roze[39] called attention to its history. Laciniation seems to have taken place at least twice in the genus *Chelidonium.* Of *C. japonicum* Thumb. occurs a var. *dissecta.*[40]

There exist several varieties of *Chelidonium majus.* Thus we have the broad-petaled form (*C. majus latipetalum*) of the Groningen Botanic Garden, the double-flowered variety and the cut-leaved one, the latter particularly interesting because the laciniation extends to the petals. During the last four years I have cultivated

[38] A cut-leaved variety of *B. pendula* is also known, *vide* Sanford, S., "A Cut-leaved Cherry Birch," *Rhodora,* **4**: 83, 1902.

[39] Roze, E., "Le *Chelidonium laciniatum* Miller," *Journ. de Bot.,* **9**: 296, 301, 338, 1895.

[40] Prain, D., "A Revision of the Genus *Chelidonium,*" *Bull. Herb. Boiss.,* **3**: 570, 1895.

The Papaveraceæ yield other instances of the reappearance of an abnormality in members of the same genus, for instance pistillody of the stamens. The most quoted instance is that of *Papaver somniferum polycephalum,* a variety which was grown more than fifty years ago in the trial grounds of the Vilmorins. Similar varieties were described by von Mohl for *P. orientale* and by Elkan for *P. dubium* (Henri van Heurck, "Notice sur une prolification axillaire floripare du *Papaver setigerum,*" *Bull. Soc. Roy. Bot. Belg.,* **2**: 329, 1863) and is said to occur also in *Macleya cordata* (Le Sourd-Dussiples et Georges Bergeron, "Note sur un cas de métamorphose ascendante," *Bull. de la Soc. bot. de France,* **8**: 348, 1861).

eight lots of *Chelidonium majus laciniatum,* two of which have double flowers, the seed being obtained through the exchange lists of various botanic gardens. These eight lots apparently represent five distinct forms. The differences are not great and probably would remain unnoticed by the casual observer. After constant association with them one can not fail to recognize the differences, however slight. But though slight, the differences are constant. They consist in the degree of laciniation as well as in degree of hirsuteness. It might be argued that these differences perhaps are due to differences in external conditions or in the age of the plants or in seasons, etc., just as the leaves produced by *Acer saccharinum* var. *Wieri,* in the latter part of the summer at the extremities of the long, slender twigs, have a lamina far more reduced than those formed earlier in the year. Roze calls attention to the fact that in his cultures of *Chelidonium laciniatum* the degree of laciniation of the leaves increased as the season advanced,[41] the petals undergoing a similar change. He also noted that the degree of laciniation increased with the amount of light received.

While we have noted that the differences between the varieties are most marked in the early part of the year, the fact that our cultures were carried out under uniform conditions as to soil, light and water supply, and that the various types are recognizable even in the late summer, seems to indicate that these forms are entitled to varietal rank. The specimen illustrated in Fig. 5 ought to set at rest all doubts upon this point. One hardly would care to account for the extreme reduction of leaf surface in this case on the basis of the influence of fluctuating variability. This form, in all probability, is identical with the *Chelidonium majus foliis et flore minutissime laciniatis* of the Hortus regius (1661), which

[41] Roze, *loc. cit.*, 339. "... si l'on suit la plante dans sa croissance, on remarque que les deux ou trois premières feuilles (après les feuilles germinatives) ont l'apparence de celles de la forme *crenatum* et les dernières celles de la forme *fumarifolium,* mais a découpures plus courtes et moins étroites."

originated in the Paris Botanical Garden from seed of *Chelidonium majus laciniatum* and to which de Candolle afterwards gave the name *C. laciniatum fumariæfolium.*[42]

A second plant in our garden represents an extreme in another direction and is intermediate between the

FIG. 5*a*. *Chelidonium majus.*

species and the variety *laciniatum*. It probably is identical with the var. *crenatum.*[43] Besides these three varieties I believe to be able to distinguish two other forms, constant from seed. It is possible that all of them originated through mutation of *C. majus laciniatum,* as did the variety *fumariæfolium*. It is equally possible that laciniate forms of *Chelidonium majus* have originated

[42] *Prod.*, 1: 123.

[43] *C. majus crenatum* Lange, Fl. dan.

more than once and directly from the parent species. This is the view taken by Clos,[44] who describes the finding by P. Barthès of a plant of *C. majus fumariæfolium* in Sorèze, Tarn. It is to be noted that these plants bore underdeveloped, seedless pods. This last seems to speak

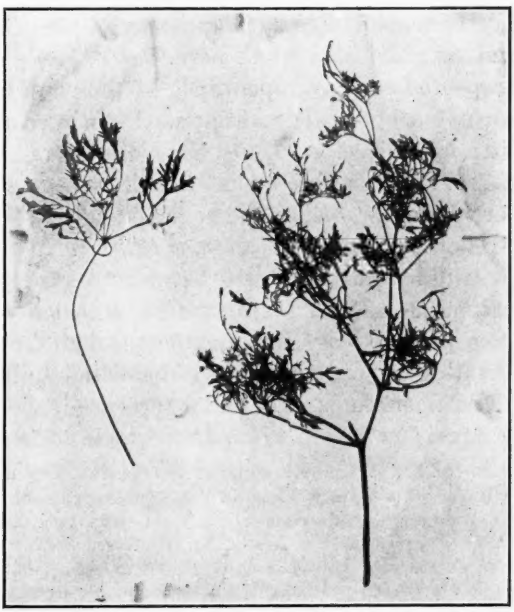

FIG. 5*b*. *C. fumariæfolium*.

in favor of the assumption of a *creatio de novo*, since plants from other stock appear fertile. To this extremely interesting point, a discussion of which falls outside the scope of the present paper, I hope to return in an article shortly to be published.

The correctness of the view that the same mutation or at least a mutation in the same general direction may take place in different stocks, must be granted *a priori*. Evidence in the support of this belief we find in the ex-

[44] Clos, D., "Réapparition de la Chélidoine a feuille de Fumeterre," *Compt. rend.*, **115**: 381, Paris, 1892.

istence of several distinct laciniate forms of different species of trees and shrubs. The varieties *heterophylla, laciniata, asplenifolia*[45] and *incisa* of *Fagus sylvatica, Alnus glutinosa laciniata, A. glutinosa quercifolia* and *A. glutinosa oxyacanthifolia* are instances to which numerous others might be added. It would seem that the laciniate forms of *Mercurialis annua,* observed by Marchant, would find a place here.[46]

The repeated sudden appearance of the same variety has been noted by various authors. Darwin, Korschinsky,[47] the late director of the St. Petersburg Botanic Garden, and de Vries[48] give numerous instances. Thiselton Dyer was able to show the repeated formation of at least two new varieties of *Cyclamen latifolium.*[49] Many, from personal experience, will be able to supply other instances. And while most of the cases which come to our notice probably are explainable through accidental transportation of seed or through Mendelian splitting of a hybrid between the species and a retrograde variety or through atavism,[50] there are others which do not admit

[45] This variety, like cut-leaved varieties of other species, not infrequently shows atavism in certain shoots. See de Vries, "Atavismus durch Samen und durch Knospen" ("Mutationstheorie," **1**: 482), and also R. G. Leavitt, "Partial Reversion in Leaves of the Fern-leaved Beech," *Rhodora,* **6**: 45, 1904; O. Paulsen, "Blivende Axelblade hos Boegen," *Bot. Tidskr.,* **24**: 281, 1902; A. Trotter, "Contributo alla teratologia vegetale," *R. S. Bot.,* Italy, **44**, 1902.

[46] This variation in the degree of laciniation within a single species ought to throw some light on "unit-characters." If we consider—as I believe generally is done—laciniation to be a "unit-character" it would seem that such a "unit-character" may be subject to considerable variation, though the degree of variation is constant or at least approximately so for each individual case. This relative stability of the varietal character of course does not prevent the extremes of each degree of variation from overlapping.

[47] Korschinsky, S., "Heterogenesis und Evolution," *Flora,* **89**, 240, 1901.

[48] "Species and Varieties," 627.

[49] Thiselton Dyer, W. T., "The Cultural Evolution of *Cyclamen latifolium,*" *Proc. Roy. Soc.,* **61**: 135, 1897. See also J. Denman, "The Sporting Peculiarity of the Persian Cyclamen," *Gard. Chron.,* 3d Ser., **29**: 266, 1900.

[50] Among the plants cultivated in the experimental grounds of D. M. Ferry & Co., of Detroit, Mich., is a variety of cabbage bearing the name

of such an interpretation. Thus the finding by Mr. W. H. Ransome, of several plants of the four-leaved variety of *Fragaria vesca* at a point about twenty miles west of Kalispel, Flathead Co., Mont. A new form, which has appeared at various times and which because of the nature of the variation is incapacitated from reproducing itself by seed, would from this very fact constitute an ideal illustration of repeated mutation, since a hybrid origin of the individuals which appeared later, is excluded. Such an instance is yielded by the wheat-ear carnation, *Dianthus Caryophyllus imbricatus*. A sterile variety, it is propagated vegetatively. First described in the eighteenth century, and since then the subject of comment on the part of several teratologists, its sudden appearance has been noted in different stocks and at various times and places.[51] Instances of similar malformations may be met with from time to time. Thus Ballard[52] describes a sunflower in which the flowers were replaced by scales.

It is a question whether the plants of *Arctium minus laciniatum* from Albion are to be considered as derived from preexisting plants of the variety or whether they have arisen *de novo*. Are they perhaps the result of a mutation of *Arctium minus?* Plants of both the species and the variety were found growing near the junction of Hannah St., Albion and the Kalamazoo River. The road at this point is bordered by a tall fence between which and the sidewalk is a space about 1½ feet in width. In a strip about 45 feet in length, among other weeds and with several specimens of the species, were found about a dozen individuals of *Arctium minus laciniatum*. Five of these were two-year-old plants, the remainder young rosets. As far as could be judged at the time, but slight differences exist between the leaves of the rosettes of the species and of those of the variety. A slight tendency

"Early Winnigstadt." For the last eight or ten years from one to three per cent. of "Green Glazed" have appeared among them.

[51] De Vries, H., "Species and Varieties," 228, 1905.

[52] *Gard. Chron.*, 3d Ser., **30**: 347, 1901.

to laciniation is all that could be observed. Perhaps the result of the cultural experiments, when a large number of rosettes can come under observation, will shed more light upon this point. But there was no danger of confusing the adult plants of the species and of the laciniate variety, for the latter presented a most striking appearance (Fig. 3). At first glance it seemed as if caterpillars or grasshoppers had destroyed the greater part of each leaf; the midrib and larger veins and here and there a small portion of the blade being left. A closer examination revealed the fact that the rosette leaves differed least from those of the normal plant. The leaves *a* and *b* in Fig. 6 show this sufficiently. The latter represents a

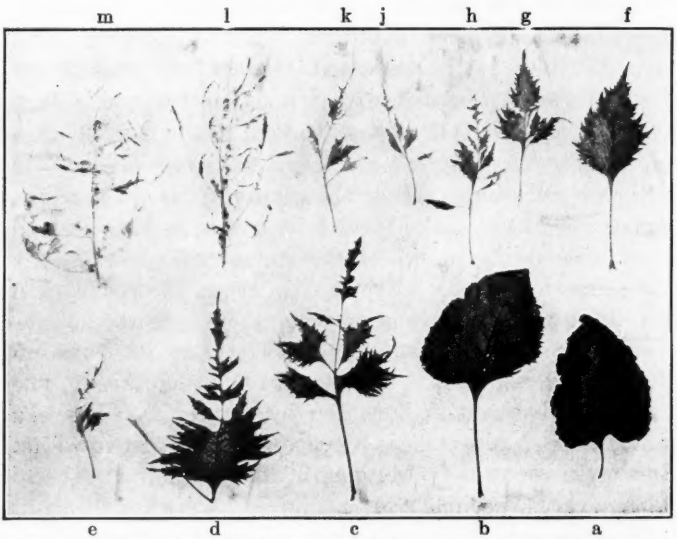

FIG. 6. *Arctium minus* and *A. minus laciniatum*. *a*, rose leaf of the species; *b-k*, leaves of the variety; *l*, *m*, inflorescences of the variety.

rosette leaf of the var. *laciniata*, the former one of the species. The next leaves possess a marked laciniation (Fig. 6 *c*, *d*, etc.). As one proceeds higher up the stem, the laciniation becomes more pronounced, till finally but a figment is left of the leaves in the region of the inflores-

cence. In fact, there are leaves which possess a midrib only.

What appears to have been the same plant has been described in a recent publication,[53] as occurring in two different places about Joliet, Ill., and near Champaign, Ill. Here the inflorescence is referred to as "irregular with numerous small sterile flowers." It is also reported from South Bend, Ind.[54] Previously its appearance had been noted near Jessup, Ind.[55] Here also the inflorescence is described as "irregular, heads numerous, mostly small, rudimentary and apparently sterile." From an article by Fernald and Wiegand[56] it is gathered that Darlington in his "Flora Cestrica" referred to a similar plant.[57]

To Professor Fernald, who saw Darlington's specimen in the Gray Herbarium, I am indebted for the following: "Darlington's sheet bears the note: var. foliis pinnatifidis vel potius grosse dentatus. West Chester, Pa., August 25, 1858. These are imperfect specimens of the plant referred to in Fl. Cestrica, p. 156; but I am not sure that it is the one spoken of in Gray's Manual. The inflorescence always has a kind of half-starved or semi-abortive appearance. W. D."

The general appearance of the inflorescence certainly suggests a teratological development, giving an impression similar to that caused by inflorescences of *Rhus glabra* infested with a certain gall. But an examination of the living plants, at least such was the case with those at Albion, at once does away with any question as to their normal condition. The peculiar ragged appearance of the flowering shoots is merely due to a progres-

[53] *The American Botanist*, **15**: 83, 1909.

[54] *The American Botanist*, **15**: 112, 1909.

[55] Brown, H. B., "A Peculiar Specimen of *Arctium*," *Plant World*, **12**: 135, fig. 2, 1909.

[56] Fernald, M. L., and Wiegand, K. M., "A Synopsis of the Species of *Arctium* in North America," *Rhodora*, **12**: 43, 1910.

[57] Darlington, W., "Flora Cestrica," 436, 1837. "A variety has been observed here, occasionally, with pinnatifid leaves." Perhaps the references to a variety with pinnatifid leaves met with in Wood's Flora and in the earlier editions of Gray's "Manual" owe their origin to this note.

sive laciniation as the leaves approach the apex, comparable to the seasonal reduction of the blades in *Acer saccharinum* var. *Wieri,* or of the various laciniate varieties of *Chelidonium majus* referred to above. Also, Professor Barr was able to gather seed. It should be stated in this connection that while the seed of the species, obtained from Albion, germinated readily and produced typical *Arctium* seedlings, there appeared in the seedpans devoted to the variety, seedlings having all the characteristics of those of *Lactuca Scariola integrata,* and these only. Seedlings of species and their varieties are as a rule so much alike that the thought at once presented itself that some seed of the wild lettuce either had become mixed with the seed of the variety or was contained in the soil used for growing the seedlings. Were either of these suppositions correct, it would seem curious that the same thing had not occurred in the case of the seed of the species. At least one of these possibilities could have been eliminated had it been possible to sow the seed in sterilized soil. As the rosettes grow older there could be no doubt as to their really belonging to *Lactuca.* While therefore these experiments yielded negative results, it still is possible that their repetition, with perhaps certain modifications, may result differently. Also an attempt should be made to obtain seed from a different source, for it is very well possible that while one lot of laciniate-leaved plants is fertile, another, perhaps of distinct origin, is sterile. We find an analogy in the case of *Chelidonium majus laciniatum* quoted above.

Unfortunately but few herbarium specimens are available for comparison with the specimen of Darlington in the Gray Herbarium. Through the courtesy of the curators of the herbaria mentioned we learn that in the herbarium of the Smithsonian Institution the variety is represented by a single specimen "collected by Alfred E. Ricksecker at Elyria, Lorain County, Ohio, August 1, 1894." It is added that it has very deeply laciniate leaves and that the venation is very different from that

of the common form. In both these respects it agrees with the Albion specimens.

From the herbarium of the New York Botanical Garden, Dr. Marshall A. Howe was kind enough to write: "We have in our herbarium apparently only one specimen of the form that you have in mind." This specimen was collected in 1865 at Uxbridge, Mass., by J. W. Robbins. Another sheet of this material is in the Gray Herbarium.

Through the courtesy of Professor William Trelease we know that a laciniate-leaved variety of the burdock is represented in the herbarium of the Missouri Botanical Garden by two herbarium sheets, the one, without date, bearing a specimen collected in Europe, the other a specimen collected at New Bedford, Mass., in 1890 by Harvey. Professor Trelease adds: "Neither has represented the extreme cutting of the leaves that yours shows, but there is enough of it to lead me to think that as extreme forms might have been collected."

Dr. Greenman, of the Field Museum of Natural History, fails to identify any material in this collection with *A. minus laciniatum*, "unless possibly a very poor specimen collected at Chelsea, Mass., Sept. 24, 1863, by J. Blake."

While it is probable that the same form occurs in Europe, thus far it does not appear to have been recorded in the floras. Inquiries on the part of my friend Dr. Jongmans, of the State Herbarium at Leyden, Holland, failed to elicit confirmatory answers, nor does the variety appear to be represented either in the Leyden herbarium nor in any of the European herbaria whose curators I have been able to consult.

It is hoped to amplify, by further inquiries, these somewhat meager data. From what we know at the present time, it would appear that *Arctium minus laciniatum* is of comparatively rare occurrence (Fig. 7). I have never met it except at Albion, though a good deal of territory was covered both here and abroad and I was looking for just such variations. Professor Barr, who has

botanized extensively in the vicinity of Albion, never has encountered it. From a glance at the map it appears not improbable that this plant, perhaps having its origin in Massachusetts, or introduced there from Europe,

Distribution of *Arctium minus laciniatum*.

FIG. 7. Map, showing successive collection of *Arctium minus laciniatum* in the United States, 1837–1910, and based upon the data available at the present time.

1. Chester Co., Pa. 1837
   West Chester, Pa. 1858
2. Chelsey, Mass. 1863
3. Uxbridge, Mass. 1865
4. New Bedford, Mass. 1890
5. Elyria, Ohio 1894
6. Jessup, Ind. 1907
7. South Bend, Ind. ..... 1909?
8. Joliet, Ill. 1909
9. Champaign, Ill. 1909
10. Albion, Mich. 1910

perhaps in ballast, gradually has been transported to various points of the compass, the area being covered by it being limited to the northeastern section of the United States. The transportation of seed, provided this is formed at all, is not unlikely. Fairly large gaps, though, appear between certain of the dates of collection. Thus, the plant does not appear to have been collected between 1837 and 1858, between 1865 and 1890, between 1894 and 1907, gaps, respectively, of eleven, fifteen and thirteen years. Yet these lacunæ very well may be accounted for on the one hand by the failure of botanists to collect the

"abnormal" specimen and on the other hand by the lack of data at our command.

There will not be wanting those who are inclined to look upon the Albion specimens as well as upon those from other localities as having originated through mutation. The mutation idea, however, involves the idea of constancy. Will the laciniate form come true to seed? If the laciniate plants at Albion are mutants one ought to be able to get a certain percentage of laciniate plants from the apparently normal plants in the same locality, eliminating in the experiment all possibility of hybrid origin. Experiments to determine this have been inaugurated, but at least four or five years must elapse before their results can be communicated. In view of our experience with other laciniate forms and provided the variety produces good seed, the question can hardly be answered in the negative, though in view of the opinions expressed by others we must reserve our decision until the question has been answered by the plant itself. For this is, after all, the only method which, though perhaps tedious at times, will lead to a sane and safe conclusion. Those in sympathy with this idea realize one need not go far from home to find material as abundant, as interesting, as instructive, as important, as can be met with at a greater distance. And while the exploration of new or difficultly accessible regions offers many attractions, he to whom such an opportunity is not given need not feel slighted, for work nearer home offers the advantage of greater facility, especially of observation. Working along lines similar to those followed by de Vries, Veit Wittrock, Dahlstedt and Nillson, it is to the botanic garden we must look for a solution of our problems.

SOME EXPERIMENTAL OBSERVATIONS CONCERNING THE BEHAVIOR OF VARIOUS BEES IN THEIR VISITS TO COTTON BLOSSOMS. II

H. A. ALLARD

U. S. DEPARTMENT OF AGRICULTURE

Experiment No. 21.—July 29. Observations continued one half hour, from 1:30 to 2:00 P.M. Three blossoms arranged in the same row.

(*a*) Control. Normal American upland cotton blossom pinned in position.

(*b*) Control. Normal American upland cotton blossom pinned in position.

(*c*) *Hawasaki* blossom entire pinned in position.

DATA FOR EXPERIMENT NO. 21

Position of Blossom	Total Inspections	Distribution by Species						Total Entrances	Distribution by Species					
		Melissodes sp.	*Elis plumipes*	Honey Bees	Butterfly	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Elis plumipes*	Honey Bees	Rutterfly	Bumble Bees	Unidentified Bees
(*a*)	12	10		2				1			1			
(*b*)	9	6		3				2			2			
(*c*)	11	8		2	1			2	1			1		

Experiments 18, 19, 20 and 21 are essentially similar, since in each a blossom of the Asiatic cotton, *Hawasaki*, is compared with American upland blossoms. The points of location of the blossoms were unchanged throughout, but the blossoms themselves were interchanged in order to check any advantage which might obtain from a particular position in the arrangement.

The *Hawasaki* blossom is smaller in size than the upland and much brighter yellow in color with conspicuous deep reddish purple petal spots inside. It was thought

that the behavior of visiting bees toward the American upland blossoms and the dissimilar Asiatic *Hawasaki* would perhaps serve to distinguish between the effects of color and form as compared with odor in inducing the visits of bees into cotton blossoms. Results indicate that the *Hawasaki* blossom, although quite unfamiliar to our native bees, is nearly as frequently inspected as our American upland blossoms.

From the readiness with which bees are led to inspect the *Hawasaki* blossoms, single detached cotton petals and the white convolvulus blossom even after it had become greatly wilted and collapsed, it is evident that they are not at first sight led to distinguish cotton blossoms from other blossoms, etc., by their characteristic form and color alone. Only by a nearer approach does the process of inspection become more discriminating in its nature with regard to the kind of blossom.

Experiment No. 22.—July 29. Period of observation one half hour, from 2:10 to 2:40 P.M. Two blossoms were used on two adjacent plants in the same row and similarly exposed.

(*a*) Blossom of American upland which had opened the day before and in consequence had become deep reddish purple in color.

(*b*) Control. Normal, recently opened cream-colored blossom of same variety.

DATA FOR EXPERIMENT NO. 22

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	12	11				1						
(*b*)	26	24			2		1	1				

Some time after midday, depending upon prevailing weather conditions, the recently expanded cream-colored cotton blossoms of that day slowly begin to close again and assume a reddish color, which by the second day is a

deep reddish purple. In connection with previous observations it was noted that those older blossoms appeared to possess little attractiveness for bees. The test was designed to reveal any differences which might serve to indicate to the bees that the purple blossom had passed the stage of usefulness to them. Although bees may in their flight indicate that the red blossom has been perceived, the inspections are usually far briefer than with the newly open blossoms of the same day. Rarely does a bee noticeably check its flight to hover over the red blossoms in the careful manner that it usually inspects those newly opened blossoms which are unchanged in color. The marked difference in color or some peculiarity of odor seems to inform the bees that an old blossom has nothing to offer them, since the pollen has been scattered and nectar is no longer secreted.

Experiment No. 23.—July 30. Time of observation one half hour, from 9:00 to 9:30 A.M. Three blossoms are arranged in the same row in equally exposed positions, as in previous experiments.

(*a*) Control. Normal upland cotton blossom pinned in position.

(*b*) Control. Normal upland cotton blossom pinned in position.

(*c*) Normal upland cotton blossoms with a drop or two of honey at base of petals within.

DATA FOR EXPERIMENT NO. 23

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	7	5			1	1	1				1	
(*b*)	6	2		1	2	1	1				1	
(*c*)	7	4		1	1	1	2	1		1		

The presence of a small quantity of honey in the blossom at (*c*) has not noticeably increased the number of entrances into it.

The single *Melissodes* which entered the blossom at (*c*) gave evidence of its appreciation of the honey which it discovered by stubbornly refusing to leave the blossom until rather violently brushed away.

Experiment No. 24.—July 30. Time of observations one half hour, from 11:00 to 11:30 A.M. Three blossoms arranged in same row. This experiment is an exact repetition of the preceding.

(*a*) Control. Normal upland cotton blossom pinned in position.

(*b*) Control. Normal upland cotton blossom pinned in position.

(*c*) Normal blossom with honey at base within.

DATA FOR EXPERIMENT NO. 24

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Ellis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Ellis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	26	16	2	4	3	1	7	3	2		2	
(*b*)	33	22	2	5	3	1	8		2	3	3	
(*c*)	14	9	1	3	1		0					

Experiment No. 25.—July 30. Time of observations one half hour, from 11:30 to 12:00 A.M. Three blossoms arranged in the same row.

(*a*) Normal cotton blossoms pinned in position as a control.

(*b*) Normal cotton blossom with honey added at base of petals within.

DATA FOR EXPERIMENT NO. 25

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Ellis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Ellis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	22	16		6			4			4		
(*b*)	19	14		4	1		1			1		
(*c*)	15	10		3	2		2			1	1	

(*c*) Normal cotton blossom pinned in position as a control.

During the forenoon the weather was dull, so that bees were less frequent in their visits.

Experiment No. 26.—August 1. Period of observations one half hour, from 9:00 to 9:30 A.M. Blossoms arranged in same row as follows:

(*a*) Normal cotton blossom with honey at base of petals within.

(*b*) Normal cotton blossom pinned in position as a control.

(*c*) Normal cotton blossom pinned in position as a control.

DATA FOR EXPERIMENT NO. 26

Position of Blossoms	Total Inspections	Distribution of Species					Total Entrances	Distribution of Species				
		Melissodes sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	26	22	1	1	1	1	0					
(*b*)	27	22		2	1	2	1			1		
(*c*)	20	17			1	2	1				1	

Experiment No. 27.—August 1. Period of observations one half hour, from 9:00 to 9:30 A.M. Blossoms are arranged in the same row.

At (*a*) an unmutilated cotton blossom was pinned in position. Portions of cotton leaves were carefully cut out and fastened outside and within the blossom in such a manner as to extend just to the margin of the petals on both sides. In this way none of the yellow color of the petals remained visible. The stamen tube, pistil, etc., projected as in a normal blossom. The blossom was practically without petals, since these were not visible, although such odors as they may have possessed could still diffuse around the blossom. A drop or two of honey was also added at the base of the petals within in order to make certain that agreeable odors were present, since

these must now necessarily constitute the sole allurement.

At (*b*) normal blossom pinned in position. The tips of the petals were lightly smeared with honey.

At (*c*) control. Normal cotton blossom pinned in position.

DATA FOR EXPERIMENT NO. 27

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	0											
(*b*)	34	23		10	1		2			2		
(*c*)	25	14		10	1		6			6		

As shown in previous experiments, the removal of the petals no longer advertises a cotton blossom to the notice of bees. The same results are obtained when the petals are no longer visible, although still attached to the blossom as at (*a*). It is natural to suppose that the presence of honey would add appreciably to the zone of alluring odors surrounding the blossom.

Without the conspicuous corolla to invite inspection, however, the bees are not led to approach sufficiently near to discover the blossom by its attendant odors alone. These results are not in agreement with some of the general conclusions of Plateau in his noteworthy memoirs: "Comment les fleures attirent les insectes." He states: "Les insectes visitent activement les inflorescences qui n'ont subi aucune mutilation mais dont la forme et les couleurs sont masquées par des feuilles vertes."[3] This would follow only when other attractive influences were actively operative, as various odors agreeable to bee visitors.

Experiment No. 28.—August 1. Time of observation one half hour, from 9:30 to 10:00 A.M. This experiment makes use of most of the material and the same positions of the preceding, with the changes as follows:

[3] *Bulletin de l'Académie royale des Sciences*, No. 11, November, 1895.

(*a*) Outer leaf covering removed from the blossom used at (*a*) in preceding experiment, thus making the outer surface of the petals visible. Honey at the base within, as before.

(*b*) Normal blossom pinned in position as a control. No honey has been added to this blossom.

(*c*) Normal blossom used in preceding experiment with petals removed.

DATA FOR EXPERIMENT NO. 28

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Ellis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Ellis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	9	3		6			0					
(*b*)	11	4		5	1	1	1			1		
(*c*)	1			1			0					

By the removal of the outer covering of the blossoms at (*a*), which in the previous experiment received no inspections, it became nearly or quite as attractive as the control at (*b*). The blossom at (*c*), however, no longer afforded means of attracting the bees. In this experiment and the previous one the corolla at (*a*) was concealed with portions of cotton leaves to guard against introducing repellent odors which may have attended the use of any other material. In the course of this experiment the number of bees flying about became much reduced toward ten o'clock, although the day was clear, hot and sunny. The writer was even forced to postpone his observations for the remainder of the forenoon owing to the scarcity of visiting bees.

Experiment No. 29.—August 1. Period of observation one half hour, from 2:00 to 2:30 P.M. The material is arranged in the same row.

At (*a*) a cotton bud not due to open until the next morning had its petals quite fully pulled open so as to resemble a naturally opening blossom.

At (*b*) a second cotton bud due to open the next morning had its petals partly pulled open.

At (*c*) a normal cotton blossom growing *in situ* as a control.

DATA FOR EXPERIMENT NO. 29

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Eiis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Eiis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	15	5		10			0					
(*b*)	2			2			0					
(*c*)	24	4		20			14			14		

In this experiment it was intended to observe the behavior of bees toward immature buds at (*a*) and (*b*) in comparison with fully expanded, mature blossoms. It was assumed that the former, owing to their immaturity, would perhaps prove less attractive to bees through the sense of smell than the fully matured blossoms. Although not definitely proved, it is reasonable to suppose that the processes of active nectar secretion simultaneously attend the unfolding of the petals and the shedding of the pollen. It would then follow that the odor of the unopened buds at (*a*) and (*b*) would prove less alluring than the blossom at (*c*).

The yellow petals of the blossom at (*a*) have served to invite frequent inspection, although at (*b*) this is not as evident. This difference may depend upon the fact that the bud at (*b*) was much less conspicuous, since the petals have been only slightly pulled open. Whatever the true explanation, the mature, fully unfolded blossom which serves as a control at (*c*) has received many more inspections, nearly 60 per cent. of which are actual entrances.

Experiment No. 30.—August 2. Period of observation one hour, from 9:30 to 10:30 A.M. Two blossoms were arranged in the same row in equally conspicuous positions.

At (*a*) a very clean, thin 5×7 glass plate was sup-

ported in front of a fully opened cotton blossom pinned in position. The surrounding cotton leaves were then carefully drawn in closely around the plate so as to overlap the edges and most of the glass surface. In this arrangement, although the blossom was plainly visible through the glass, only a small portion of the glass surface remained in view.

At (*b*) control. A fully opened cotton blossom was pinned in position.

DATA FOR EXPERIMENT NO. 30

Position of Blossoms	Total Inspections	Distribution by Species					Total Entrances	Distribution by Species				
		Melissodes sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees		*Melissodes* sp.	*Elis plumipes*	Honey Bees	Bumble Bees	Unidentified Bees
(*a*)	18	6		3	4	5	0					
(*b*)	37	20	1	7	4	5	9			5	4	

Of those bees which attempted to inspect the blossom at (*a*), eight flew more or less forcibly against the glass, including two small unidentified bees, one *Bombus* sp., two honey bees and three *Melissodes*. One small bee tried persistently several times to fly through the glass toward the blossom just behind it. It is at once obvious that the blossom at (*a*) invited inspection by passing bees solely through the sense of sight.

Experiment No. 31.—August 9. Observations continued one hour, from 9:00 to 10:00 A.M.

Two blossoms were used in the same row as before. A box of thin wood was carefully constructed for this experiment. The dimensions were such that both cover and bottom were made of thin clear glass by using for each a 5×7 glass plate. These plates fitted tightly in lateral grooves. The box was about 4 inches deep, so that the end of a cotton branch together with its leaves and blossoms could be carefully pushed into a natural position within. By sliding the glass cover into place the box became practically air-tight. The blossom was plainly visible to passing bees, although any attractive

odors which it diffused could no longer act as allurements. When placed in position among the cotton limbs the box and glass were almost completely concealed by drawing in and fastening around it a number of the surrounding leaves. This box enclosed the blossom at (*a*).

At (*b*) control. A natural blossom pinned in position. The blossom at (*a*) received only two inspections, both by small, unidentified bees. The blossom at (*b*) received only five inspections, three being by *Melissodes* and two by honey bees. There were no entrances at (*b*).

Experiment No. 32.—August 9. Observations continued for one half hour, from 10 to 10:30 A.M. This experiment was identical with the preceding, except a third artificial blossom was added.

(*a*) Same blossom enclosed in the glass case as used at (*a*) in Experiment 31.

(*b*) The same control blossom pinned in position.

(*c*) An artificial paper blossom of crepe paper simulating a cotton blossom in color.

The blossom at (*a*) received one inspection by a *Melissodes* which hovered in front of the glass a few seconds only.

(*b*) Received eight inspections, which include two entrances by honey bees. The six inspections were entirely by Melissodes. Three bees inspected the artificial paper blossoms at (*c*), including one each by a *Melissodes,* an unidentified bee, and a honey bee, which paused for a few seconds over the blossom but did not enter. During the last few days bee visitors have been rather too infrequent for satisfactory work, probably in part owing to the partly cloudy forenoons.

Experiment No. 33.—August 11. Observations continued for about one half hour, from 9:00 to 9:30 A.M. Three blossoms are arranged in a row.

At (*a*) three petals were placed in position on a leaf which was spread out flat and held between two thin clean 5×7 glass plates bound firmly together. This was placed in position among the branches of a plant and was nearly concealed by overlapping around it a number of cotton

leaves. In this arrangement the yellow petal color still remained perceptible to the visual powers of bees.

At (*b*) the detached petals of a cotton blossom were enclosed in a 250-c.c. graduated flask which was stoppered and fastened among the cotton leaves. The yellow petals were plainly visible through the clear thin glass of the flask.

At (*c*) a normal cotton blossom as a control.

(*a*) Received no inspections.

(*b*) Received one inspection by a honey bee which touched the flask.

(*c*) Received three inspections by honey bees. Two bees did not enter the blossom but alighted outside to get at the extra-involucral nectaries. During this experiment the bees were too infrequent visitors to make any results conclusive.

Experiment No. 34.—August 12. Time of observations 45 minutes, from 1:30 to 2:15 P.M. This experiment was an exact duplicate of the previous one.

(*a*) Petals of cotton blossom on a leaf between glass plates as at (*a*) in Experiment 33.

(*b*) Petals of cotton blossoms enclosed in a flask as at (*b*) in Experiment 33.

(*c*) Normal blossoms growing *in situ* as a control.

The blossom at (*a*) was twice inspected by *Melissodes*. The petals in the flask at (*b*) were inspected two times by bees, once by a honey bee and once by a small, unidentified bee. The blossom at (*c*) was inspected six times, including five entrances. One inspection was made by a small, unidentified bee, four entrances were by honey bees, and one entrance by a *Melissodes*.

For several days it was rather difficult to secure satisfactory data, as the bees were much less frequent visitors. The species of *Melissodes,* which were extremely common at the beginning of the experiments finally became far less common, although honey bees greatly increased. It is very interesting to note that many honey bees finally began to confine their visits solely to the outer involucral nectaries instead of entering the blos-

soms. This change of habit seemed to become quite general at about the same period, for the writer noted it in all parts of the cotton field.

Throughout the period of observations the bees by their behavior and varying numbers showed themselves extremely sensitive to atmospheric changes, temperature relations, air movements, moisture, sunshine, etc. At times conditions even too obscure for human perception may have regulated their activities. The composition of the bee fauna to be observed in cotton fields shows much variation, depending upon the time of day, prevailing weather and seasonal influences. The position and exposure of the cotton field with relation to various local physiographic features, as type of soil, nearness to woods, swamps, hills and other crops also greatly influence the relative numbers and kinds of bees.

While carrying on his observations the writer noted that the bees, *Melissodes,* were exceedingly abundant among cotton grown on certain heavy, red-clay soils. These bees were much less abundant in fields on the lighter, sandy loams in some other localities. Honey bees are especially noticeable near bee trees or domestic hives. The marked abundance of other bees in particular localities likewise probably depends upon the proximity of the plants to their favorite breeding places.

Nectar glands are especially abundant on the cotton plant, including the leaves as well as the blossoms. The blossoms are supplied with several sets of nectaries. Cotton blossoms with their abundant supplies of readily accessible pollen and nectar and their open structure exclude few insect visitors. It follows that a considerable number of species of bees, wasps and other insects are at all times especially common visitors among cotton blossoms.

During the time the experiments previously described were in progress nearly 2,000 bees were observed to perceive, inspect or enter the blossoms and other material involved. 1,645 of these visits were distributed as follows: 1,381 or 83.9 per cent. were by species of *Melis-*

sodes. 130 or 7.8 per cent. were by honey bees. 40 or 2.4 per cent. were by bumble bees. 83 or 5 per cent. were by various unidentified bees.

Eleven visits were made by *Elis plumipes* and one by a large butterfly. The size and yellow color of the petals serve to make cotton blossoms particularly conspicuous in contrast with their shaded background of dark green foliage. Once visiting insects have entered a cotton field, there is little doubt but that their visual powers almost wholly enable them to discover the blossoms. This is indicated by those experiments where the corolla of certain blossoms has been covered or entirely removed, since following this procedure the remaining portions of the blossoms were unvisited. The size and general appearance of cotton blossoms do not appear to be of great importance in initiating the process of inspection, since a single petal may receive as many inspections as the control. It is of interest to note in this connection that in experiments 14 and 15 the bees did not discriminate between the white convolvulus and cotton blossoms at least until after closer inspection. When such artificial material as cloth or paper was used, although the color more or less resembled cotton petals, the bees were rarely induced to inspect it closely. This discrimination may depend upon perceptible differences in color and texture rather than the presence of repellent odors which the material possessed. Many eminent observers have adduced a great deal of evidence which proves beyond doubt that bees develop keen powers of discernment in their associations with the structural details of different flowers.

The actual number of entrances into cotton blossoms is small in comparison with those instances when blossoms have been merely perceived or inspected. The writer's observations show that of 1,061 inspections of the control blossoms only 129, or 12.1 per cent., were actual entrances. One hundred and twenty of these entrances were distributed among the several kinds of bees, as follows: 45, or 37.5 per cent., were by *Melissodes;*

45, or 37.5 per cent., were by honey bees; 6, or 5.0 per cent., were by *Elis plumipes;* 16, or 13.3 per cent., were by bumble bees; 8, or 6.6 per cent., were by various small unidentified bees. A single entrance was made by a large butterfly.

Although it seems clear that the corolla of cotton blossoms invites the first approach of the bees through their visual sense, it is not so easy to determine the relative importance of the sense of sight and smell involved in their nearer inspections. Just why do so few bees decide to enter? In their careful inspection of a single petal or a suspicious blossom is the sense of sight alone involved? Except for a single *Elis plumipes,* no bee has ever alighted upon detached cotton petals, although these have served to attract attention quite as often as the control blossoms. It is not unusual, however, for the bees to inspect these structures very intently, almost touching the surface in their movements over them. The bees have just as persistently refused to enter all artificial blossoms or blossoms mutilated by removing a part or all of the petals. In experiment 6 a bee was completely deceived by the unreal structure at (*c*) made to simulate an expanding bud by the use of actual cotton petals and portions of a cotton leaf. In this instance the bee inspected and finally squeezed itself down between the petals. Unless the fresh petals themselves possess a characteristic odor, odors such as might emanate from a normal blossom were entirely lacking and, therefore, could not have induced the bee to enter. Plateau concludes that visual conspicuousness by means of bright colors is of no advantage whatever to blossoms so far as insect visitors are concerned. He claims that if in nature all blossoms were green like the surrounding foliage, they would be just as readily discovered by bees and other insects in virtue of their odor. The writer's experiments in the field indicate that conspicuousness in virtue of their position and yellow coloration is a very important factor in leading bees and other insects to perceive cotton blossoms.

It does not appear that the addition of small quantities of honey either upon the petals themselves or at the base of the flower within appreciably increased the inspections or entrances, although if a bee chanced to discover this honey, its fondness for it was evinced by its strong reluctance to leave.

It is probable that the inspections are largely of a visual nature, though these may be supplemented by certain odors when the blossoms are more closely examined. Many noted observers, especially Müller, have adduced abundant evidence to prove that the visual power of bees becomes very critical in their behavior toward minute differences of floral structure.

The bee *Melissodes bimaculata,* which is probably by far the commonest of this genus in certain cotton fields at Thompson's Mills, behaves somewhat differently from other bees in its inspections. Its flight is swift and irregular, and its entrance into a blossom is usually preceded by a more careful examination than that resorted to by bumble bees, the common honey bee, or the wasp *Elis plumipes.* It is the usual procedure for the last to fly straight into a blossom or almost drop into it from above, apparently without troubling itself about any preliminary examination. The bumble bees too are less fastidious in their closer inspection.

Many instances are recorded which illustrate the habit of bees to profit by previous successful or unsuccessful experiences. A sort of memory by association is developed so that older, more experienced bees often appear to work among blossoms to much better advantage than younger bees. As an illustration of the influence of previous association upon subsequent behavior, the writer cites the following interesting instance which has come under his observation at Thompson's Mills, North Georgia. It has been mentioned that the common honey bee sooner or later discovers the outer involucral nectaries of cotton blossoms and visits them very constantly, seemingly in preference to the inner floral

nectaries. These particular nectaries, although present in our common American cottons, are never found on the Asiatic cottons, *Hawasaki,* etc. In the writer's variety tests these foreign cottons have been grown side by side and sometimes intermingled in the rows with the American cottons. The honey bees, in passing from blossom to blossom, visiting each time the outer involucral nectaries occasionally met the Asiatic variety. The previous association with the American cottons and their outer involucral nectaries led these bees to visit without success similar structures of the unfamiliar Asiatic variety. The bees quickly recognized their error after alighting and left the blossoms. Is this procedure other than the working of an associative memory? The writer is of the opinion that the honey bees do not discover these extra-floral nectaries until after more or less association with cotton blossoms each summer. This habit of the honey bee appears to become more noticeable later in the season. During the season of 1908 it appeared to be very general. It is a habit which seems to be almost wholly confined to honey bees.

These visits of the bees to the outer basal portion of the Asiatic cotton blossoms indicate that the visual powers alone were employed throughout the process. Although the bees first discovered the blossoms by their conspicuous petals, it is evident that they were led to search for outer involucral nectaries on the Asiatic cotton blossoms solely by their familiarity with the general form and structure of cotton blossoms.

As an illustration of associative memory this behavior of the honey bees is exactly similar to the behavior of certain bees in experiments conducted by Pérez[4], who used scarlet pelargoniums which are not visited by bees, since those flowers possess no nectar. He added honey to certain flowers which were then visited by bees, and says:

[4] Pérez, J., "Notes Zoologiques" (*Actes de la Société Linnéenne de Bordeaux,* Vol. XLVII, série V, tome VII, pp. 250–251, 1894).

La couleur écarlate s'était si bien associée dans leur souvenir à l'idée du miel, qu'elles se passaient à la fin sur des fleurs de cette couleur n'en ayant pas reçu, et ne les quittaient qu' apres s'être assurées, par un examen scrupuleux et persistant, qu'elles n'avaient rien à y recueillir.

A translation of his own words follows: "Scarlet color and honey had become so closely associated in their minds that they finally alighted upon flowers of the same color which had received none, and would not leave until they had assured themselves by a scrupulous and persistent examination that these flowers had nothing to offer them." Plateau gets precisely the same results when he says:

Lorsque l'insecte avait ainsi absorbé le liquide d'un certain nombre defleurs miellees, il lui arrivait de se diriger vers les Pelargoniums non nunis de miel.[5]

"After the insects had gathered honey from a number of flowers to which it had been added, they were then led to visit Pelargonium blossoms which had not received it." These observations are hardly in agreement with the rather radical conclusions of Bethe[6] that bees are devoid of sense impressions, and are incapable of profiting by previous experiences, that their activities are purely reflex, mechanical. Forel, Wasman, Buttel-Reepen, Huber and others have shown, nevertheless, that bees do profit by previous experiences and form habits under certain conditions. Lovell[7] has shown that once bees have been accustomed to visiting a certain color, they tend to return to it regularly until it is to their advantage to change. Once the bees have entered the cotton fields, it is quite obvious that they are led to discover the blossoms by the conspicuous corolla. It would be interesting to learn just how they find the fields themselves. Although a single cotton blossom does not

[5] *Bulletin de l'Academie royale de Belgique*, 3e série, 33, January, 1897.

[6] Bethe Albrecht, "Durfen wir Ameisen und Beinen psychische Qualitäten zuschrieben?" in *Arch. f. d. ges. Physiologie*, Bd. 70, 1898.

[7] Lovell, John H., "The Color Sense of the Honey Bee: Can Bees Distinguish Colors?" AMER. NAT., Vol. XLIV, No. 527, November, 1910.

seem especially odoriferous, it is not improbable that a field of well-developed cotton plants may readily advertise its location to the olfactory sense of bees by odoriferous clouds, so to speak, which are wafted away with every air-movement. During a hot, sunny afternoon the combined odors volatilizing from the great numbers of foliage and floral nectaries, the pollen, etc., must be very considerable. Especially during clear sunny days following periods of cloudy or rainy weather bees become unusually active and numerous. Many of these visitors have no doubt learned the location of the fields by previous association.

THE DISTRIBUTION OF PURE LINE MEANS

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SEVERAL times recently we have been told that the means of a character in a series of pure lines form a "Quetelet's Curve."[1] Some of those responsible for this assertion seem to attribute a particular virtue to "Quetelet's Law," and to feel that the statement that the means of a series of pure lines form a chance curve furnishes uncontrovertible evidence for the genotype theory of heredity. The questions which interest the biologist are, first, whether the statement is true in the sense that it is made on a sufficient body of actual observations, and second, what is the general biological significance to be attached to it, if true.

But among these biologists the interpretation of the facts has apparently preceded the demonstration of the existence of the facts themselves. Now while it is not at all unlikely that the means of genotypes—if such entities in Johannsen's sense of the term do exist in nature—form a chance curve, it by no means follows that conversely a series of averages which can be arranged in a symmetrical variation polygon proves or even suggests the existence of differentiated pure lines or biotypes. Yet just such differences in means are being accepted and cited without criticism as valid evidence in support of Johannsen's sweeping generalizations.

A case in point is a paper by Roemer[2] on pure lines in peas. It is with regret that one criticizes Roemer's

[1] Compare, for example, in this connection: Nilsson-Ehle, *Bot. Not.*, 1907, pp. 113–140; Lang, *Zeitschr. f. Ind. Abst.- u. Vererbungsl.*, Vol. 4, pp. 15–16, 1910; Spillman, AMER. NAT., Vol. 44, p. 761, 1910; Pearl, AMER. NAT., Vol. 45, p. 423, 1911.

[2] Roemer, T., "Variabilitätsstudien," *Arch. f. Rassen- u. Gesellsch.-Biologie*, Vol. 7, pp. 397–469, 1910.

paper. It is an exceedingly laborious *Arbeit* and apparently done with scrupulous care. One who himself has experienced the labor of calculating a few tables of constants has sympathy for a worker who has industriously filled pages with them. But the tenability of the genotype theory is one of the most pressing of current evolutionary problems, and all available evidence must be scrutinized. Roemer's data are chosen for two very excellent reasons, the first of which is that of all of the men who have discussed the disposition of the means of pure lines in a "Quetelet's Curve," he is, so far as I am aware, the only one who has put on record sufficient data for a critical test of his conclusions. If without overtrying the case, as the lawyers have it, we can give the second reason, it is that Roemer's data and conclusions have been accepted as perfectly valid by genotype specialists. One of them, for example, says:

> The work is essentially a confirmation, with another plant, of Johannsen's epoch-making investigations on beans, though it lacks any extensive studies on the effect of selection within the pure line. The essential objective point of Roemer's research is rather to determine the biometric characteristics of pure lines as such in relation to the general population. Among the more important general results are the following:
>
> 1. The different biotypes in a population arrange themselves in frequency distributions in accord with Quetelet's Law.
>
> 2. No relation was found to exist between the variability of the biotypes (*i. e.*, variation within the general population) and variation within the pure lines.

Our problem is twofold. First, we have to determine whether Roemer is really justified in regarding his lines as differentiated. Second, we have to inquire concerning the critical value of his data as evidence in support of the genotype theory of heredity. Incidently we shall make the first of these problems serve as an illustration of the use of a coefficient of individual prepotency recently proposed in these pages.[3]

[3] Harris, J. Arthur, "A Coefficient of Individual Prepotency for Students of Heredity," AMER. NAT., Vol. 45, pp. 471–478. 1911.

II. The Problem of Differentiation in Roemer's Pure Lines

The method of Roemer's study was very simple. In 1908 a population of pea plants was grown from a sample of ordinary seed. In 1909 the offspring of each of a number of these plants was studied separately, and the means of several characters calculated. By a comparison of selected pairs of these means Roemer concludes that the several lines differ from each other, and by a seriation of all the line means he obtains the Quetelet's curve.

Such evidence as this can not be accepted. Every mean calculated on a sample of individuals is more or less untrustworthy as a measure of the character in individuals in general, because of the errors of random sampling, and in attaching significance to a series of averages this fact must be fully taken into account. It can not adequately be allowed for by a comparison of selected cases with their probable errors.

First Test. A Comparison of the Variability within the "Pure Line" with that of the "Population"

One of the tests of the presence of differentiated "biotypes," "genotypes" or "pure lines" within a "population" is the comparison of the intra-line with the population variability. If both be the same there is no justification in the assumption that the population is composed of a number of differentiated pure lines.[4] If the variability of the population is greater than that of the individual lines it may (or may not) comprise a series of "genotypes."

The reason for this is obvious. The standard deviation within the pure line, σ, describes only the differences occurring among the individuals of the group, while Σ, the standard deviation of the group, includes also the amounts by which the several lines are differentiated.

[4] This is, of course, under condition that the individuals of the several pure lines are not reared under conditions which tend to increase artificially their variability beyond that of the population.

Roemer does not give us the population standard deviations for the several characters in 1909 but only the averages, $m_1, m_2, m_3, \cdots, m_s$, and the standard deviations $\sigma_1, \sigma_2, \sigma_3, \cdots, \sigma_s$. We may approximate the desired constants very closely indeed[5] by the following method.

Let there be s samples or pure lines of $n_1, n_2, n_3, \cdots, n_s$ individuals each, with means $m_1, m_2, m_3, \cdots, m_s$, and standard deviations $\sigma_1, \sigma_2, \sigma_3, \cdots, \sigma_s$. These form the population $S(n) = N$, for which the physical constants Σ and M are desired.

The mean is clearly $M = S(nm)/S(n)$.

In calculating the S.D. we may take the first two rough moments, ν_1', ν_2', about any point we please and adjust by the familiar formula $\sigma^2 = \mu_2 = \nu_2' - \nu_1'^2$. If the moments be taken about 0[6] $\nu_1' = M$, and it is at once clear that for the population

$$\Sigma = \sqrt{\frac{S[n(m^2 + \sigma^2)]}{S(n)} - \left(\frac{S(nm)}{S(n)}\right)^2},$$

when S indicates a summation for all groups or lines.[7]

The population constants have been calculated by these formulæ for all the characters of Roemer's two large series. He has given population constants, M and Σ, for the 1908 series, the parents of the 1909 plants.

The two are conveniently laid side by side for comparison in Table I.[8] The data in hand hardly seem to justify detailed comparison with reference to probable

[5] There is no approximation in the formula. The accuracy in practise depends solely upon the trustworthiness of the original m's and σ's, and upon the number of decimal places retained in the arithmetical routine.

[6] For several advantages in doing this see AMER. NAT., Vol. 44, pp. 693–699. 1910.

[7] The application of the formula to Roemer's data is of course exceedingly laborious, involving as it does the determination and summation by pairs of 3,108 squares, and the summation of the products of their totals by the frequencies upon which they are based. The publication of a little tabulated data would have reduced many days' labor necessary for a critical test of his results to a few hours.

[8] The constants for 1908 are taken from Roemer's Table I. Those for 1909 are calculated by the formulæ given above.

errors. It will be noted at once that for all the characters the mean is higher in 1909[9]—indeed for some characters in the "Kapital Erbse" it is almost double that found in 1908! With one exception the standard

TABLE I

COMPARISON OF PHYSICAL CONSTANTS FOR 1908 AND 1909 POPULATIONS

Character and Comparison	Averages		Standard Deviations		Coefficient of Variation	
	Gelbe Viktoria-Erbse	Svalöfs Kapital-Erbse	Gelbe Viktoria-Erbse	Svalöfs Kapital-Erbse	Gelbe Viktoria-Erbse	Svalöfs Kapital-Erbse
Weight of Plant						
1908 Population	13.09	7.99	4.250	2.815	32.47	35.23
1909 "	20.82	20.39	6.568	7.127	31.54	34.95
1909/1908 Ratio	1.59	2.55	1.545	2.531	.97	.99
Length of Stem						
1908 Population	114.96	78.96	12.985	12.575	11.30	15.95
1909 "	136.81	158.42	16.331	20.163	11.93	12.73
1909/1908 Ratio	1.19	2.01	1.257	1.603	1.06	.80
Thickness of Stem						
1908 Population	24.03	20.50	2.766	2.081	11.50	10.15
1909 "	25.20	24.05	2.390	2.933	9.48	12.19
1909/1908 Ratio	1.05	1.17	.864	1.409	.82	1.20
Number of Pods						
1908 Population	4.59	5.62	1.364	1.805	20.72	32.12
1909 "	6.48	11.54	1.987	4.263	30.66	36.95
1909/1908 Ratio	1.41	2.05	1.456	2.361	1.48	1.15
Weight of Pods						
1908 Population	9.71	5.76	3.192	2.184	32.80	37.95
1909 "	11.28	10.26	4.290	4.407	38.03	42.98
1909/1908 Ratio	1.16	1.78	1.343	2.017	1.16	1.13
Number of Seeds						
1908 Population	19.64	24.02	6.267	8.418	31.91	35.05
1909 "	26.60	45.11	9.162	18.633	34.44	41.31
1909/1908 Ratio	1.35	1.88	1.461	2.213	1.08	1.18
Weight of Seeds						
1908 Population	7.63	4.56	2.569	1.833	33.67	40.21
1909 "	8.56	7.26	3.511	3.376	40.99	46.49
1909/1908 Ratio	1.12	1.59	1.366	1.841	1.22	1.16

deviations in 1909 are higher than those in 1908. Mean and standard deviation are generally closely correlated, and this doubtless accounts for the greater variability of the 1909 series. Possibly, however, the 1909 plants

[9] Roemer states that conditions for growth in 1909 were superior to those in 1908.

were grown under conditions more heterogeneous than those to which the 1908 plants were exposed. In the second case, the S.D. might be directly raised, *i. e.*, heterogeneity in the crop may be merely a reflection of heterogeneity in the substratum.

There is no way of determining whether Roemer's cultural conditions were more heterogeneous in 1909 than in 1908, but it must be noted that *in ten of the fourteen cases* the coefficient of variation is higher in 1909.

Two ratios are to be examined,

$$\frac{\text{Mean Pure Line Variability}}{\text{Parental Population Variability}},$$

$$\frac{\text{Mean Pure Line Variability}}{\text{General Population Variability}}.$$

Consider first the ratio of the mean pure line to the parental population variability. If the offspring of the individual parents are differentiated we should expect to find the mean variability of the pure lines less than that of the parent population, providing, of course, that innate tendencies are not obscured by environmental factors. Table II[10] gives the necessary data.

Now the remarkable thing about these standard deviations is that in the most cases the variability within the individual "pure lines" in 1909 is greater than that of a mixture of all the pure lines in 1908. The excess is very striking in several cases. Of the fourteen comparisons, thirteen show a higher variability within the pure line than in the population. For the "Viktoria"

[10] For 1908 the population Σ and C.V. are from Roemer's Table I. The 1909 population Σ and C.V. have been calculated by the formulæ given above. The mean pure line standard deviations have been taken from Roemer's Tables II–III. None of the constants have been rechecked, since the original data are not available. The mean value of 12.13 for thickness of stem in Table II is obviously a printer's slip for 2.13. The mean pure line coefficients of variation are from Roemer's Table X. These were not calculated by dividing the sum of the coefficients of variation of the individual pure lines by the number of lines, but by dividing the mean standard deviation of the pure lines by the mean average of the pure lines.

the average M.P.L./Parental ratio is 1.327 while for the "Kapital" it is 1.996. The "pure line" variability is thus from 30 to 100 per cent. in excess of that of the population.

TABLE II

COMPARISONS OF MEAN PURE LINE AND POPULATION VARIABILITY

Character and Comparison	1908–1909. Standard Deviations		1908–1909. Coefficient of Variation		1909–1909. Standard Deviations	
	Gelbe Viktoria-Erbse	Svalöfs Kapital-Erbse	Gelbe Viktoria-Erbse	Svalöfs Kapital-Erbse	Gelbe Viktoria-Erbse	Svalöfs Kapital-Erbse
Weight of Stem						
Population	4.250	2.815	32.47	35.23	6.568	7.127
Mean Pure Line	5.96	6.44	28.53	31.40	5.96	6.44
M.P.L./Pop. Ratio	1.402	2.288	.88	.89	.907	.904
Length of Stem						
Population	12.985	12.575	11.30	15.95	16.331	20.163
Mean Pure Line	13.80	15.98	10.05	10.05	13.80	15.98
M.P.L./Pop. Ratio	1.063	1.271	.89	.63	.845	.792
Thickness of Stem						
Population	2.766	2.081	11.50	10.15	2.390	2.933
Mean Pure Line	2.13	2.04	8.45	8.46	2.13	2.04
M.P.L./Pop. Ratio	.770	.980	.73	.83	.891	.696
Number of Pods						
Population	1.364	1.805	29 72	32.12	1.987	4.263
Mean Pure Line	1.80	3.92	27.19	34.00	1.80	3.92
M.P.L./Pop. Ratio	1.320	2.172	.91	1.06	.906	.920
Weight of Pods						
Population	3.192	2.184	32.80	37.95	4.290	4.407
Mean Pure Line	3.80	3.95	33.84	38.50	3.80	3.95
M.P.L./Pop. Ratio	1.190	1.809	1.03	1.01	.885	.896
Number of Seeds						
Population	6.267	8.418	31.91	35.05	9.163	18.633
Mean Pure Line	8 01	16.60	33.30	36.80	8.01	16.60
M.P.L./Pop. Ratio	1.278	1.972	1.04	1.05	.874	.891
Weight of Seeds						
Population	2.569	1.833	33.67	40.21	3.511	3.376
Mean Pure Line	3.17	3.04	37.05	41.90	3.17	3.04
M.P.L./Pop. Ratio	1.234	1.658	1.10	1.04	.903	.900

The explanation of this anomalous result is first to be sought in the higher means (with the associated higher variability) in the 1909 plants. Basing the comparison on the coefficients of variation in order to eliminate, in so far as possible, the influence of the means, we note that seven of the ratios are greater and seven

are less than unity, while for all the mean is .936. On an average, therefore, the pure lines have 93.6 per cent. as much variability as the population.

The second comparison, that between the variability of the individual pure lines and the population which they form, can be made on the basis of the standard deviations alone since the means are the same. This comparison (the last two columns of Table II) shows that in both series and for every character the variability written, the line is less than that for the population. The lowest ratio is .70, the highest is .92 and the mean is .858. This test indicates that they are differentiated. This is, of course, the conclusion which Roemer drew from his selected individual comparisons.

Second Test. The Deviation of the Pure Line Means from the Population Mean

For characters measurable on a quantitative scale the test for the deviation of the offspring of an individual from its population is given by

$$(m - M) \pm .67449 \sqrt{\frac{\Sigma^2}{N} + \frac{\sigma^2}{n}\left(1 - \frac{2n}{N}\right) - \frac{n(M-m)^2}{N(N-n)}}.$$

Where m and M, σ and Σ, n and N are the means, standard deviations, and numbers of individuals for the family and the population, respectively.[11]

For reasons which will be apparent to the reader later, the data which are given us do not justify calculations to a high degree of refinement.[12] We therefore approximate in every point possible.

The expressions

$$1 - \frac{2n}{n}, \quad \frac{n(M-m)^2}{N(N-n)}$$

[11] AMER. NAT., Vol. 45, pp. 471–478. 1911.

[12] Furthermore, I have serious misgivings that Roemer's lines comprise so few individuals each that the coefficient suggested must be used with caution. It is not needful to consider the point in greater detail here.

may be disregarded, since with such relatively low values of n as those of Roemer's data the first is practically unity, while the second is generally insignificant and may always be neglected, having a maximum value of *circa* .010, and in the majority of the cases falling far towards zero. The values of Σ^2/N are given in Table III. In practically every case the inclusion of Σ^2/N in

TABLE III

VALUES OF Σ^2/N

Character	Gelbe Viktoria Erbse	Svalöfs Kapital Erbse
1. Weight of plant	.0233	.0292
2. Length of stem	.1442	.9204
3. Thickness of stem	.0031	.0049
4. Number of pods	.0021	.0105
5. Weight of pods	.0100	.0112
6. Number of seeds	.0454	.1997
7. Weight of seeds	.0067	.0066

formula would change the end result only insignificantly, and since we are working roughly it may be omitted throughout.

We have thus reduced the formula to the fundamental term $\sqrt{\sigma^2/n}$. Fortunately for us, Roemer has not used the correct formula for the probable error of the mean but has given Johannsen's "Mittlerer Fehler," $\sigma/\sqrt{n} = \sqrt{\sigma^2/n}$. We now simply determine $m - M$[13] and $(m - M)/(\sigma/\sqrt{n})$ for each of his lines. Table IV gives the ratios.

Apparently there can be no question concerning the reality of differentiation in Roemer's lines. If the differences $(m - M)$ were due purely to random sampling from a homogeneous population, we should expect the

[13] This second test was carried out before the first, and so before the actual population means and variabilities were available. The means used were Roemer's means of pure line averages, as given in his Table IX. These would be the same as the population means if all the lines had the same n. As a matter of fact, the agreement is very close in all. In two cases only did I modify Roemer's means—changing number of pods from 6.6 to 6.5 and weight of pods from 11.2 to 11.3, in the "Gelbe Viktoria Erbse."

TABLE IV

Ratio of Deviation to Probable Error	Character[14] in Gelbe Viktoria Erbse							Character in Svalöfs Kapital Erbse						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
−15.5 to −14.5	—	—	—	—	—	—	—	—	1	—	—	—	—	—
−14.5 to −13.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−13.5 to −12.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
−12.5 to −11.5	—	—	—	—	—	—	—	—	—	—	—	—	—	1
−11.5 to −10.5	—	—	—	—	—	—	—	—	1	—	—	—	—	—
−10.5 to − 9.5	—	—	—	—	—	—	—	—	1	—	—	—	—	—
− 9.5 to − 8.5	—	—	—	—	—	—	—	—	1	—	—	—	—	—
− 8.5 to − 7.5	—	—	—	—	—	—	—	—	—	—	1	—	—	—
− 7.5 to − 6.5	—	2	—	—	—	—	—	—	—	—	—	1	—	1
− 6.5 to − 5.5	—	—	—	1	1	—	—	—	1	—	1	—	1	—
− 5.5 to − 4.5	4	3	—	—	3	3	2	2	1	1	2	—	1	1
− 4.5 to − 3.5	1	5	3	4	1	4	4	5	6	2	5	5	2	3
− 3.5 to − 2.5	6	12	8	5	4	3	5	7	2	2	1	4	4	6
− 2.5 to − 1.5	13	12	18	13	15	18	14	8	8	15	7	10	11	13
− 1.5 to − 0.5	29	19	19	24	24	25	25	19	15	25	15	24	19	16
− 0.5 to + 0.5	24	13	29	31	28	22	24	26	18	30	36	17	22	19
+ 0.5 to + 1.5	25	21	13	23	22	24	23	26	25	12	21	28	27	30
+ 1.5 to + 2.5	8	14	10	9	9	13	12	9	13	13	12	14	15	12
+ 2.5 to + 3.5	5	6	9	2	5	1	4	3	7	3	4	2	4	4
+ 3.5 to + 4.5	1	2	4	2	1	2	1	—	3	2	2	1	—	—
+ 4.5 to + 5.5	—	3	1	1	—	—	—	1	1	1	—	1	1	1
+ 5.5 to + 6.5	—	2	1	—	—	1	—	1	1	1	—	—	—	—
+ 6.5 to + 7.5	—	—	—	—	—	—	—	—	1	—	—	—	—	—
+ 7.5 to + 8.5	—	1	—	—	1	—	1	—	1	—	—	—	—	—
+ 8.5 to + 9.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+ 9.5 to + 10.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+ 10.5 to + 11.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
+ 11.5 to + 12.5	—	—	—	—	1	—	—	—	—	—	—	—	—	—

ratios $(m - M)/\sigma_{(m-M)}$ to have a standard deviation of $1 \pm .67449/\sqrt{2s}$, where s is the number of lines involved. The constants are given in Table V.

TABLE V

Character	Gelbe Viktoria Erbse	Svalöfs Kapital Erbse
1. Weight of plant	1.738 ± .077	1.886 ± .087
2. Length of stem	2.620 ± .117	3.209 ± .148
3. Thickness of stem	2.008 ± .089	1.768 ± .082
4. Number of pods	1.717 ± .076	1.955 ± .090
5. Weight of pods	2.213 ± .098	1.839 ± .085
6. Number of seeds	1.857 ± .083	1.759 ± .081
7. Weight of seeds	1.895 ± .084	2.188 ± .101

Now we remember that Roemer's individual lines are represented by so few individuals that our formula may not give absolutely trustworthy results, and that in case

[14] Numbers of characters are the same as in Tables III and V.

it does not, the discrepancy is in favor of the pure linist. But comparing these values with $1.000 \pm .044$ for "Viktoria" and $1.000 \pm .046$ for "Kapital," I think we must admit that the evidence is strongly in favor of a differentiation in these lines of peas.

III. The Bearing of These Data upon the Genotype Theory of Heredity

To the conclusion that these pure lines of peas are differentiated among themselves and that speaking roughly their means "form a Quetelet's Curve," there can be no objection, although this conclusion is by no means justified by Roemer's own analysis of his data. The assumption that these facts lend any support whatever to the genotype theory[15] seems to me to rest not only upon the most slipshod reasoning, but upon a complete disregard of simple biological precautions.

The chief of the pertinent reasons follow.

First. *There is no Evidence of Line or Genotypic Constancy or Heredity.*

By definition the genotype is a rigid organic entity, distinguished by breeding true from generation to generation, with the exception of mutations which are completely inherited and fluctuations which are not inherited at all. The mean of the line remains the same from generation to generation (except for rises and falls due to periodic environmental changes); the variations around these means are absolutely incapable of inheritance.

Roemer and his supporters of course assume this to be true for the *Pisum* series dealt with, but no fragment of evidence is adduced to show either (*a*) that these means remain the same from generation to generation, or (*b*) that selection within the pure line is ineffective. The condition is even worse than this. Roemer measured the

[15] The cardinal points of the genotype theory have been tersely, and I believe fairly, summarized elsewhere in these pages. See AMER. NAT., Vol. 45, pp. 346–363, 1911.

characters of the parent plants which furnished the seed from which his various pure lines were grown, but he neither determines whether there is any parental correlation in the population nor gives us the data from which this might be determined. To be sure, one may determine from his data that the variability within the individual line is less than that of the population, but this might be as easily attributed to the much-scouted "Galton's Law" as to genotypic heredity; possibly it is to be referred to some factor quite outside inheritance.[16] In fine, it is impossible to determine anything at all about inheritance from Roemer's data.

Second. *The Possibility of Environmental Heterogeneity is not Adequately Taken into Account.*

One of the first precautions of the experimental breeder should be to make sure that the environmental conditions to which his materials are subjected are not so heterogeneous as to vitiate entirely any conclusions concerning innate factors. Two watch glasses of *Paramecia* may present highly different environmental conditions. Food and housing are important factors in the egg records of poultry. Peas differ from row to row, or within the row, because of slight differences in the substratum. But experimenters now-a-days are so obsessed with the idea of rigid "unit characters," "determiners" and "genes" that little attention is paid to environmental influences; they are so absorbed in "analyzing" the "germ plasm" that they forget to make proper allowance for factors which may so modify the soma—which is the only available index of the germ plasm of an individual —that it is misleading as a guide to hereditary tendencies.

From my own experience in experimental cultures it seems quite possible that the differences in Roemer's lines are due to lack of uniformity in the substratum. One is

[16] For instance, de Vries has several times suggested that the feeding of the parent plant may have an effect on the offspring. I personally do not believe that this could be a sensible source of differentiation in Rôemer's peas, but it is one of the factors which should be taken into account by a critical student of the problem.

not much impressed with the consistency of his results. Not only are his means and standard deviations much higher in 1909 than in 1908, but the relative variabilities are also higher in ten out of fourteen cases. To be sure, he has used the conventional precautions. He describes his field as a "gleichmässiger humoser Lehmboden," and states that the fertilizer was mixed with soil before application and distributed as evenly as possible. But for an organism so responsive to environmental influences as the garden pea,[17] and in a problem of this delicacy, these precautions are not at all sufficient. It is quite clear[18] that the seeds from each parent were planted together in rows, and if the soil differed at all from one part of the field to another the tendency would be for this heterogeneity to induce a differentiation in the crop.

If it be urged that we do not *know* that the differentiation in Roemer's means are due to environmental heterogeneity, the reply is simple. It is the duty of those who claim genotypic rank for observed differences to prove that their results are not due merely to faulty experimental conditions.

Third. *One or Both of Roemer's "Populations" are in Reality "Pure Lines."*

By definition a pure line is the offspring of a single individual of a continually self-fertilizing or vegetatively propagating organism. They may or may not be differentiated. Genotypists assume that generally they are both differentiated and highly constant. Selection within the line is absolutely incapable of effecting any change.

Now the curious thing about Roemer's material is that at least one, and possibly both, of the two populations suitable for our examination are in reality pure lines. Whether the "Individualauslese" by which the "Gelbe Viktoria Erbse" was developed gave rise to a pure line depends largely upon the stringency with which it was

[17] Roemer observes that the pea is exceedingly susceptible to environmental influences.

[18] See Roemer, *l. c.*, pp. 404–405.

carried out. Concerning "Svalöfs Kapital Erbse" there can be no doubt. The original plant was selected at Svalöf in 1896. Whether a further selection within the offspring of this plant was made, Roemer was unable to determine, but of the ancestry of his seed he felt quite certain.

Truly this is an anomalous state of affairs! Analyzed by the best available statistical methods, Roemer's data certainly indicate that the lines studied are significantly differentiated. Pure-line specialists dispense with any statistical analysis at all and accept the data as "a confirmation . . . of Johannsen's epoch-making investigations on beans." Yet if the differentiation in these lines be due to anything other than faulty experimental conditions, the observations described destroy entirely the value of Johannsen's theory by showing that heritable variations may occur in great numbers in the pure line.

IV. Summary and Conclusions

1. The statement that the means of the pure lines of a population form a "Quetelet's Curve" is now being made by genotypists. If it is true that an apparently homogeneous population is composed of a large number of slightly differentiated genotypes, it seems *a priori* not unlikely that their means will be arranged according to "Quetelet's Law." The question which concerns the biologist is whether this is, as a matter of fact, the condition found in nature. The object of the present rather laborious study has been to test the validity of this assertion on the basis of available facts. Roemer's data for pure lines in peas are the only passably satisfactory published series available.

2. Such a problem has two phases. It is first necessary to determine by adequate statistical tests that the lines in question may be reasonably regarded as differentiated biologically—*i. e.*, that the differences between them cannot be explained as the errors of random sampling, such

as give one a low or a high hand at cards. It is then allowable to consider the biological interpretation of the differences.

3. Two tests for differentiation were applied: (*a*) the mean intra-line variability was compared with the population variability, and (*b*) the significance of the deviation of individual line means from the population mean was tested by a coefficient of individual prepotency recently suggested. Both of these tests indicate sensible and statistically significant differences between the lines. These differences may be said to be distributed according to "Quetelet's Law" as the term is loosely used by biologists.

4. This fact *per se* furnishes no evidence at all for the genotypic nature of the differences in Roemer's lines. Indeed, throughout Roemer's work there is no conclusive evidence of any kind concerning any problem of heredity. At least one (and possibly both) of his series of material is from his own explicit statements in reality a pure line. The difference observed within these lines and considered by him and other pure linists to be of genotypic value and a confirmation of Johannsen's results with beans are probably merely the result of faulty experimental conditions. If they are not, Roemer's evidence goes squarely against Johannsen's theory.

COLD SPRING HARBOR, L. I.,
July 19, 1911.

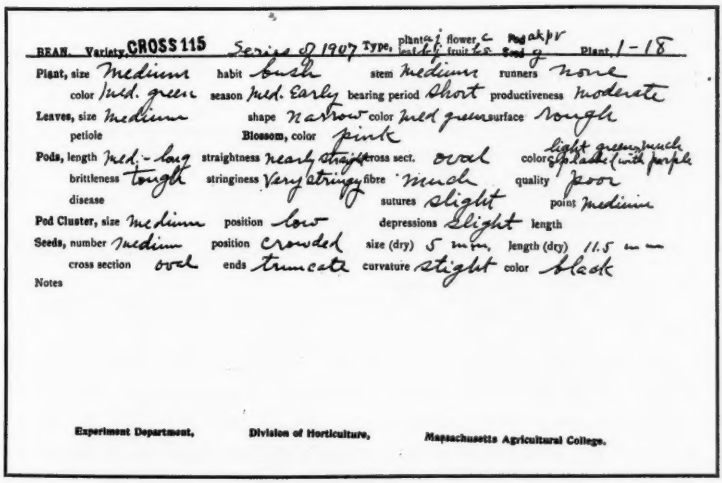
SHORTER ARTICLES AND DISCUSSION

A SYSTEM OF RECORDING MENDELIAN OBSERVATIONS

In any experimental investigation the importance of making full, definite and at the same time simple and easily understood notes can hardly be overestimated. To record all pertinent observations in a convenient and easily accessible manner with the least expenditure of time and energy should be the object of the observer.

In connection with some investigations in plant breeding at the Massachusetts Experiment Station a system of records has been devised for use in experiments where segregation of characters occurs that has worked very well in practise and may be found suggestive to other observers who are investigating Mendelism and handling a considerable number of plants.

The records are kept on 5×8 index cards, though 4×6 cards might be preferred by some. All observations pertaining


BEAN. Variety CROSS 115 Series of 1907 Type, plant c, flower c, Pod ak pr, leaf b, fruit c c, Seed g, Plant 1-18

Plant, size Medium habit bush stem medium runners none
color Med. green season med. Early bearing period Short productiveness moderate

Leaves, size Medium shape Narrow color med green surface rough
petiole Blossom, color pink

Pods, length med - long straightness nearly straight cross sect. oval color light green, much splashed with purple
brittleness tough stringiness very stringy fibre much quality poor
disease sutures slight point medium

Pod Cluster, size medium position low depressions slight length

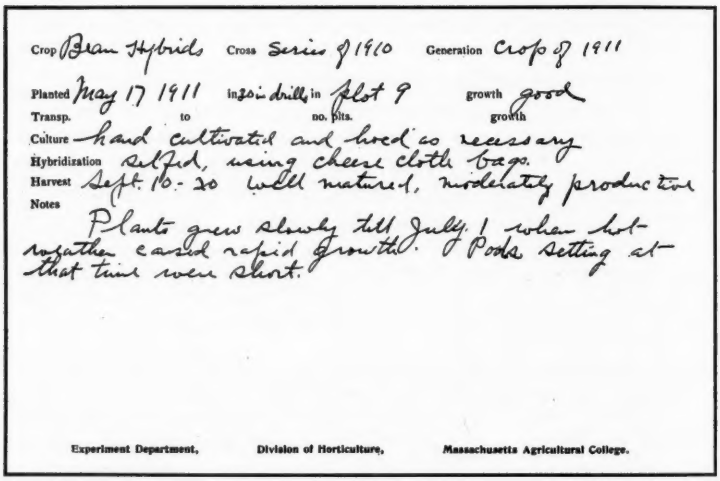
Seeds, number medium position crowded size (dry) 5 mm. length (dry) 11.5 m m
cross section oval ends truncate curvature slight color black

Notes

Experiment Department, Division of Horticulture, Massachusetts Agricultural College.

FIG. 1. Description Card.

to parent varieties or the F_1 generation are kept on blue cards and subsequent generations are recorded on buff, salmon and white cards. This provides for four generations which is about as many as are usually desired, but other colors are available if needed for subsequent generations. Four different blanks in each color are provided known as (1) description cards, (2) culture cards, (3) type cards and (4) blanks which are plain ruled cards used for miscellaneous notes. A description card applicable to beans is shown in Fig. 1. Cards suitable to other plants may, of course, be easily devised. These cards are not often used but are occasionally very convenient. Figure 2 shows a cul-


Crop Bean Hybrids Cross Series of 1910 Generation Crop of 1911

Planted May 17 1911 in soil drill in plot 9 growth good
Transp. to no. plts. growth

Culture hand cultivated and hoed as necessary
Hybridization selfed, using cheese cloth bags.
Harvest Sept. 10-20 well matured, moderately productive
Notes

Plants grew slowly till July 1 when hot weather caused rapid growth. Pods setting at that time were short.

Experiment Department, Division of Horticulture, Massachusetts Agricultural College.

FIG. 2. Culture Card.

ture card that is used for any crop under observation and gives all necessary information concerning the care, cultivation and growth of any lot of plants.

The type card shown in Fig. 3 is the most important and distinctive feature of the system. A single line is given to each plant and furnishes opportunity for recording easily and quickly a wide range of observations. Each hybrid between parent varieties is given a serial number that is stamped at the top of the first column and beneath this are entered the numbers of the individual plants. Hybrids between different individuals of a variety are distinguished by the addition of a letter to this num-

ber which is discontinued when it appears that the plants are similar in constitution. Numbers given in each generation are carried along separated by a hyphen in the manner usually followed in such work.

Each character that appears is designated by a letter of the

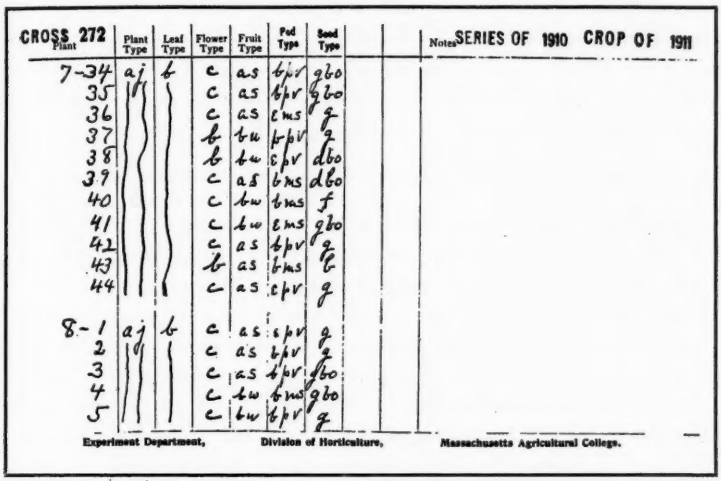

CROSS 272
Plant
Plant Type
Leaf Type
Flower Type
Fruit Type
Pod Type
Seed Type
Notes
SERIES OF 1910 CROP OF 1911
7-34 aj b c as bpr qbo
35 c as bpr qbo
36 c as cms q
37 b bu bpr q
38 b bu cpr dbo
39 c as bns dbo
40 c bw bns f
41 c bw cms qbo
42 c as bpr q
43 b as bns b
44 c as cpr q
8-1 aj b c as bpr q
2 c as bpr q
3 c as bpr qbo
4 c bw bns qbo
5 c bw bpr q
Experiment Department, Division of Horticulture, Massachusetts Agricultural College.

FIG. 3. Type Card.

alphabet and in order to secure opportunity for recording a large number of characters they are more or less arbitrarily grouped, each group having if needed the whole twenty-six letters available. Each group is assigned a column in the card. In order to illustrate this a portion of the type designations we have used with beans is here given which with Fig. 3 will clearly show the application of the system. The same blank may of course be used with plants other than beans.

Plant type:
- *a* = stems green,
- *b* = stems with purple lines,
- *c* = stems purple tinged,
- *h* = pole form,
- *i* = runner form,
- *j* = bush form.

Flower types:
- *a* = white,
- *b* = light pink,

Fruit types:
- *a* = pod flat,
- *b* = pod oval,
- *e* = pod round,
- *s* = pod straight,
- *u* = pod curved.

Pod types:
- *a* = light green,
- *b* = medium green,
- *c* = dark green,

c = pink.

Leaf types:
a = light green,
b = medium green,
e = medium yellow,
h = broad,
i = medium.

m = no fiber,
p = much fiber,
s = stringless,
v = very stringy.

Seed types:
a = white,
b = buff,
c = yellow,
d = light red,
g = black,
m = medium eye,
o = dark mottling.

The notes shown in Fig. 3 give the following information: The cross in number 272 which is shown by a separate list and by a neighboring guide card to be Prolific Black Wax × Mohawk. This cross was one of those made in 1910 (Series 1910) and these plants were grown in 1911. (Crop of 1911.) The color of the card shows at once the generation. Plant 7–34 had green stems and was a bush bean. The leaf was medium green, the flower pink, the pod flat, straight, green, tough and stringy. The seed was black and buff mottled, the black predominating, as shown by o indicating dark mottling. All these observations are very quickly recorded, once they are determined and the record is brief, convenient, definite and easily summarized.

It is of course necessary to record clearly and positively just what is signified by each letter. Most characters appear in some established variety and may be fixed by referring to them. Full description or preserved material may supplement such references when necessary. Additional blank columns are provided to allow for more extended observations or they may be used in connection with the space to the right for brief special notes on the individual plant. If more extended notes regarding any plant or group of plants are desired, a description card or a blank card of the appropriate color may be inserted at any point for their accommodation. Photographs or drawings might also be easily filed if desirable.

We have used these cards for the past three years for recording observations on many thousands of plants, not only beans but several other kinds as well, and the system has given good satisfaction. If it contains any features useful to other observers the purpose of this article will be fulfilled.

J. K. SHAW.

THE MASSACHUSETTS AGRICULTURAL COLLEGE